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<td>Outcome Survey</td>
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Course Design Data
Course: AE 311 – Low Speed Aerodynamics (3: 3, 1) – Required Core Course


Prerequisites: AE-301, EE-300, and EE-332.


Course Learning Objectives: By the completion of the course, the students should be able to:

1. Basic laws
   1.1. Derive the general governing equations from the fundamental principles.
   1.2. State the assumptions for incompressible potential flow and use them to simplify the general equations.

2. Potential Flow Theory
   2.1. Define vorticity and circulation and distinguish between rotational and irrotational flows.
   2.2. Define and compute stream function, streamlines, potential function, equipotential lines for a flow and calculate each, if they exist.
   2.3. State and implement the general approach for the solution of incompressible potential flow.
   2.4. Analyze (i.e., calculate velocities, pressures, stream function, potential function, stagnation points, streamlines, equipotential lines, circulation around bodies, etc.) the elementary flows (uniform, source/sink, doublet, vortex) as well as any combination of them (lifting/non-lifting flow over a circular cylinder, Rankin oval, etc.)
   2.5. Implement the source panel method to compute pressure and velocity on non-lifting surfaces.

3. Airfoil and Boundary Layer Theories
   3.1. Explain and apply the Kutta Condition for any sharp edge of a wing (i.e., what it means physically and how it is enforced mathematically.)
   3.2. State Kelvin's theorem and explain how it is implemented to setup the vortex system of an airfoil.
   3.3. Derive the fundamental equation of Thin Airfoil Theory.
   3.4. Use thin airfoil theory to compute aerodynamic characteristics of airfoils (lift and drag at various angles of attack, pitching moment about various points, a.c. location, c.p. location, etc.).
   3.5. Describe and implement the vortex panel method to compute aerodynamic characteristics for thick airfoils.
   3.6. Describe qualitatively and quantitatively both laminar and turbulent boundary layers in terms of their thickness, velocity profiles and shear stress variation along a surface.
   3.7. Use the Boundary Layer Theory to calculate the skin friction drag, estimate the pressure drag of bodies, and predict location on the surface where boundary layer separation is likely to occur.
   3.8. Describe the aerodynamic characteristics of airfoils and their impact on airfoil design.
   3.9. Use software packages (JavaFoil) to investigate the effects of thickness and camber on the aerodynamic characteristics (lift slope, aerodynamic center) of airfoils.
   3.10. Use software packages (JavaFoil) to investigate the effects of airfoil geometrical characteristics and the angle of attack on the boundary layer behavior and how it is related to changes in lift and drag.

4. Finite Wing Theory
   4.1. Describe the flow field around wings of finite span and Explain the generation of induced drag.
   4.2. Describe Prandtl's lifting-line theory and state its limitations.
   4.3. Apply the results from Prandtl's lifting-line theory to calculate the aerodynamic characteristics of airplane wings.
   4.4. Identify wing aerodynamic parameters and recognize their impact on wing design.

5. Global/Social/Contemporary Problems Related to Aerodynamics
   5.1. List several examples of regional, national, and/or global contemporary problems related to aerodynamics (ex. environmental issues, natural resources and energy conservation, etc.) articulate a problem/position statement for each, and explain what makes these issues particularly relevant to the present time.
   5.2. Identify possible solutions to these problems, as well as any limitations of these solutions.
Course Topics and their Duration:

<table>
<thead>
<tr>
<th>Course Topics</th>
<th>Duration in weeks</th>
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<tbody>
<tr>
<td>1. Basic laws</td>
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<tr>
<td>2. Potential Flow Theory</td>
<td>3</td>
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<tr>
<td>3. Airfoil and Boundary Layer Theories</td>
<td>4</td>
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<tr>
<td>4. Finite Wing Theory</td>
<td>4</td>
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<tr>
<td>5. Global/Social/Contemporary Problems Related to Aerodynamics</td>
<td>1</td>
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</tbody>
</table>

Class Schedule:
- **Lecture**: two 80 minutes sessions per week
- **Tutorials**: one 100 minutes session per week

Course Contribution to Professional Component:
- Engineering science: 75%
- Engineering design: 25%

Course Relationship to Program Outcomes:

<table>
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<th>Program Outcomes</th>
<th>ABET Outcomes</th>
<th>Program Criteria</th>
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<td>Highest Attainable Level of Learning</td>
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Prepared by: Dr. Ibraheem. M. AL-Qadi

Last Updated: May 2008
# Course Calendar

**Course:**

AE311 – Low Speed Aerodynamics  
Spring 2008

<table>
<thead>
<tr>
<th>WEEK #1</th>
<th>Lectures:</th>
<th>Introduction, derivation of conservation laws.</th>
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<tbody>
<tr>
<td>WEEK #2</td>
<td>Lectures:</td>
<td>Dynamics of incompressible ideal flow: vorticity, circulation, stream function, velocity potential, Bernoulli and Laplace equations.</td>
</tr>
<tr>
<td>WEEK #3</td>
<td>Lectures:</td>
<td>Elementary flows; source and sink, vortex, doublet and uniform flows, Superposition, Rankin oval, flow around a cylinder.</td>
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<tr>
<td>WEEK #4</td>
<td>Lectures:</td>
<td>Source Panel Methods, flow around a rotating cylinder. Kelvin’s theorem, starting vortex, Kutta-Joukovski theorem, Kutta condition.</td>
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<tr>
<td>WEEK #5</td>
<td>Lectures:</td>
<td>Thin airfoil theory, symmetric thin airfoil, pitching moment, aerodynamic center, center of pressure, General thin airfoil, zero lift angle, pitching moment, aerodynamic center, center of pressure, flapped airfoils</td>
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</tbody>
</table>

| WEEK #6 | 1st Major Exam: | (material presented in week 1,2, 3, and 4) |

| WEEK #7 | Lectures: | Airfoils of arbitrary thickness and camber (vortex panel method). Incompressible boundary layer equations: introduction, deriving equations, exact solutions, Boundary layer over a flat plate. |
| Projects | 1st Project Assignment |

| WEEK #8 | Lectures: | Von Karman integral method, Thwaites' integral method, transition, turbulent boundary layer. |
## Course Calendar (continued)

### Course:
AE311 – Low Speed Aerodynamics

#### Spring 2008

<table>
<thead>
<tr>
<th>WEEK #9</th>
<th>Lectures:</th>
<th>Characteristic parameters for airfoils, Airfoil geometry, pressure distributions, relation between Cp and performance, relating geometry and Cp, Airfoil design, Software Package: Javafoil.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2nd Major Exams:</td>
<td>(material presented in week 5,7 and 8)</td>
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<tr>
<td>Projects</td>
<td>1st Project due on Sunday, 2nd Project Assignment</td>
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</table>

<table>
<thead>
<tr>
<th>WEEK #10</th>
<th>Lectures:</th>
<th>Characteristic parameters for wings, Finite Wing: laws of vortex motion, observed characteristics, trailing vortices, down wash, induced drag. General load distribution.</th>
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<tr>
<td>WEEK #11</td>
<td>Lectures:</td>
<td>Elliptic load distribution, Three-Dimensional Vortex Lattice Method, Software Package: Tornado</td>
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<td>WEEK #12</td>
<td>Lectures:</td>
<td>Wing design parameters, relating wing geometry and lift distribution, lift distributions and performance, wing design in more details.</td>
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<tr>
<td>Projects</td>
<td>2nd Project due on Tuesday – 3rd Project Assignment</td>
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<thead>
<tr>
<th>WEEK #13</th>
<th>Lectures:</th>
<th>Configuration Aerodynamics: Aircraft Configuration Design Options, sizing considerations, Delta wings, leading edge extensions, Canard Aircraft, Tailless Aircraft, High angle of attack aerodynamics.</th>
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<tbody>
<tr>
<td></td>
<td>3rd Major Exams:</td>
<td>(material presented in week 10 and 11)</td>
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<td>Projects</td>
<td>3rd Project due on Tuesday</td>
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<tr>
<th>WEEK #14</th>
<th>Lectures:</th>
<th>Problems related to Aerodynamics</th>
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<tbody>
<tr>
<td>Projects</td>
<td>4th Project Assignment</td>
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<th>WEEK #16</th>
<th>Lectures:</th>
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<tr>
<th>WEEK #17</th>
<th>Lectures:</th>
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<tbody>
<tr>
<td>Projects</td>
<td>4th Project due on Sunday</td>
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</tbody>
</table>
Course Instructional Methods and Assessment Tools

Course: AE311 – Low Speed Aerodynamics Spring 2008

Course Instructional Methods:
Instructional methods of the course include the following activities:

1. Lectures:
   Instructor will teach the topics of the course emphasizing on the course related learning objectives through two eighty minutes lecture meetings per week. Lectures will; in most cases, have a mix of formal lecturing and active learning.

2. Tutorials:
   During the tutorials (one 100 minutes meeting per week), the instructor will solve example problems related to the recently introduced topic. The instructor will also discuss with the students the problems they faced while trying to solve the assigned homework problems. Some of the tutorials are devoted for training the students on software packages needed in the course.

3. Project:
   A number of projects are assigned throughout the semester. Some of the projects involve topics that require data and information collection while other projects involve implementation of theory through the development of computer codes. Other projects involve the use of analysis tools to design and/or evaluate airfoils sections and wings including high-lift device and control surfaces. Students are grouped in teams, each of 4 students. Each team should submit report and give a presentation of their work.

Direct Assessment Tools:
Student learning outcomes will be measured through the following direct assessment tools:
1. Exams: Three major exams will be held during the semester at the end of each major topic plus a final exam at the end of the semester.
2. Projects Report and presentation
Course Design
Goal – Learning Objectives – Coverage Hours – Passing Criteria and CLO-PO Mapping Matrix

Course : AE311 – Low Speed Aerodynamics

Course Goal:
The course is intended to develop the student’s ability to model flow field around aerodynamic configurations in order to:

- Estimate the aerodynamic forces and moments acting on such configurations.
- Design aerodynamic configurations to generate certain lift force with minimum drag force and/or other constraints.

Course Learning Objectives:
1. Basic laws
   1.1. Derive the general governing equations from the fundamental principles.
   1.2. State the assumptions for incompressible potential flow and use them to simplify the general equations.

2. Potential Flow Theory
   2.1. Define vorticity and circulation and distinguish between rotational and irrotational flows.
   2.2. Define and compute stream function, streamlines, potential function, equipotential lines for a flow and calculate each, if they exist.
   2.3. State and implement the general approach for the solution of incompressible potential flow.
   2.4. Analyze (i.e., calculate velocities, pressures, stream function, potential function, stagnation points, streamlines, equipotential lines, circulation around bodies, etc.) the elementary flows (uniform, source/sink, doublet, vortex) as well as any combination of them (lifting/non-lifting flow over a circular cylinder, Rankin oval, etc.)
   2.5. Implement the source panel method to compute pressure and velocity on non-lifting surfaces.
   2.6. State Kutta-Joukowski Theorem and use it to compute lift.

3. Airfoil and Boundary Layer Theories
   3.1. Explain and apply the Kutta Condition for any sharp edge of a wing (i.e., what it means physically and how it is enforced mathematically)
   3.2. State Kelvin's theorem and explain how it is implemented to setup the vortex system of an airfoil.
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   3.10. Use software packages (JavaFoil) to investigate the effects of airfoil geometrical characteristics and the angle of attack on the boundary layer behavior and how it is related to changes in lift and drag.

4. Finite Wing Theory
   4.1. Describe the flow field around wings of finite span and Explain the generation of induced drag.
   4.2. Describe Prandtl's lifting-line theory and state its limitations.
   4.3. Apply the results from Prandtl's lifting-line theory to calculate the aerodynamic characteristics of airplane wings.
   4.4. Identify wing aerodynamic parameters and recognize their impact on wing design.
   4.5. Describe and implement (through the software package TORNADO) the Vortex Lattice Method to compute aerodynamic characteristics of wings and wing-tail-canard configurations (including high-lift device and control surfaces).

5. Global/Social/Contemporary Problems Related to Aerodynamics
   5.1. List several examples of regional, national, and/or global contemporary problems related to aerodynamics (ex. environmental issues, natural resources and energy conservation, etc.) articulate a problem/position statement for each, and explain what makes these issues particularly relevant to the present time.
   5.2. Identify possible solutions to these problems, as well as any limitations of these solutions.
### Course Learning Objectives – Program Outcomes Matrix:

<table>
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<tr>
<th>Program Outcomes</th>
<th>3a</th>
<th>3b</th>
<th>3c</th>
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<thead>
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<th>Course Learning Objectives</th>
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<td><strong>Topic 1:</strong> Basic Laws</td>
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Maximum attainable level of learning: 1: Low level (knowledge & Comprehension), 2: Medium (Application & Analysis), 3: High (Synthesis & Evaluation)

### Performance Targets (Passing Criteria):

<table>
<thead>
<tr>
<th>Direct Performance targets</th>
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<tbody>
<tr>
<td>1. 60% of the class students’ score over 60% in each course learning objective and each supported program outcome</td>
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<td>2. the class average is at least 60% in each course learning objective and each supported program outcome</td>
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</table>
## Aeronautical Eng. Dept. AE311 Course Articulation Matrix

<table>
<thead>
<tr>
<th>Course No.</th>
<th>AE 311</th>
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### Level of Learning (Lo) & Learning Outcomes

<table>
<thead>
<tr>
<th><strong>Level of Learning</strong></th>
<th><strong>A</strong></th>
<th><strong>B</strong></th>
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<td><strong>Program Outcomes</strong></td>
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### Topics & Learning Objectives

#### 1. Basic Laws
1.1 Define the general governing equations from the fundamental principles.
1.2 State the assumptions for an approximate potential flow set to make it amenable for analytical solution.

#### 2. Potential Flow Theory
2.1 Define static and dynamic pressures and distinguish between the two.
2.2 Define and compare stream function, potential, potential function, and velocity potential.
2.3 Define and compare streamlines, equipotential lines, and stream tube.
2.4 Define the general approach for solving potential flow problems.

#### 3. Airfoil and Boundary Layer Theory
3.1 Identify the basic principle of the Euler Equation for an ideal flow.
3.2 State the equation and explain how it is used to predict the pressure distribution on an airfoil.
3.3 Derive the basic equation of the Euler Equation Theory.
3.4 Identify and explain the characteristics of the inviscid flow.
3.5 Describe the boundary layer and explain the characteristics of the boundary layer.
3.6 Describe the characteristics of the boundary layer and explain the characteristics of the boundary layer.
3.7 Describe the characteristics of the boundary layer and explain the characteristics of the boundary layer.
3.8 Describe and explain the characteristics of the boundary layer and explain the characteristics of the boundary layer.
3.9 Describe and explain the characteristics of the boundary layer and explain the characteristics of the boundary layer.
3.10 Describe the characteristics of the boundary layer and explain the characteristics of the boundary layer.

#### 4. Fluid Dynamic Theory
4.1 Define the basic principles of fluid dynamics and outline their limitations.
4.2 State the assumptions for an approximate potential flow set to make it amenable for analytical solution.
4.3 Describe the characteristics of the boundary layer and explain the characteristics of the boundary layer.
4.4 Describe and explain the characteristics of the boundary layer and explain the characteristics of the boundary layer.

#### Global Issues/Contemporary Problems Related to Aeronautics
Global issues and contemporary problems related to aeronautics include environmental concerns, national security, and energy consumption. These topics provide an overview of the role of aerospace engineering in the modern world.
### Summary of Direct & Indirect Assessment Tools

**Course Learning Objectives Survey**

1. **Identify the potential percolation equation for the fundamental principles.**
2. **Evaluate the accuracy of the potential percolation flow and use these to suggest the potential evaluation.**
3. **Apply the percolation method to calculate the potential flow.**
4. **Apply the percolation method to calculate the potential flow.**
5. **Apply the percolation method to calculate the potential flow.**
6. **Identify the potential percolation equation for the fundamental principles.**
7. **Evaluate the accuracy of the potential percolation flow and use these to suggest the potential evaluation.**
8. **Apply the percolation method to calculate the potential flow.**
9. **Apply the percolation method to calculate the potential flow.**
10. **Identify the potential percolation equation for the fundamental principles.**

**Course Evaluation Method**

**Course Learning Objectives Survey**

1. **Identify the potential percolation equation for the fundamental principles.**
2. **Evaluate the accuracy of the potential percolation flow and use these to suggest the potential evaluation.**
3. **Apply the percolation method to calculate the potential flow.**
4. **Apply the percolation method to calculate the potential flow.**
5. **Apply the percolation method to calculate the potential flow.**
6. **Identify the potential percolation equation for the fundamental principles.**
7. **Evaluate the accuracy of the potential percolation flow and use these to suggest the potential evaluation.**
8. **Apply the percolation method to calculate the potential flow.**
9. **Apply the percolation method to calculate the potential flow.**
10. **Identify the potential percolation equation for the fundamental principles.**
Course Assessment Data
## 2.1 Indirect Course Assessment tools

### Outcomes Surveyes

**DEPARTMENT OF Aeronautical Engineering**

Indirect Assessment of Program Outcomes
Course Level Survey

**COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009**

**Outcome (a): an ability to apply knowledge of mathematics, science, and engineering**

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.1</td>
<td></td>
<td>Apply mathematics in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.2</td>
<td></td>
<td>Apply calculus (differentiation, integration, etc.) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.3</td>
<td></td>
<td>Use differential equations in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.4</td>
<td></td>
<td>Use linear algebra (matrices, systems of equations, etc.) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.5</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>a.6</td>
<td></td>
<td>Apply equilibrium principles and Newton’s laws (including free-body diagrams) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.7</td>
<td></td>
<td>Apply physics concepts (friction, thermal/fluid concepts etc.) in the solution of engineering</td>
</tr>
<tr>
<td>a.8</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

No. of Attributes: 6

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.

**Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints.**

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?</th>
</tr>
</thead>
<tbody>
<tr>
<td>c.1</td>
<td></td>
<td>Develop a flow chart of the design process?</td>
</tr>
<tr>
<td>c.2</td>
<td></td>
<td>Define “real world” problems in practical (engineering) terms?</td>
</tr>
<tr>
<td>c.3</td>
<td></td>
<td>Investigate and evaluate pre-correlated solutions for the need they are trying to address?</td>
</tr>
<tr>
<td>c.4</td>
<td></td>
<td>Develop constraints and criteria for evaluation?</td>
</tr>
<tr>
<td>c.5</td>
<td></td>
<td>Develop and analyze alternative solutions?</td>
</tr>
<tr>
<td>c.6</td>
<td></td>
<td>Choose the “best solution” considering the trade-offs between the various solutions?</td>
</tr>
<tr>
<td>c.7</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>c.8</td>
<td></td>
<td>Communicate the results of the design orally as well as in a written report (sell the design)?</td>
</tr>
<tr>
<td>c.9</td>
<td></td>
<td>Build a prototype and demonstrate that it meets performance specifications?</td>
</tr>
<tr>
<td>c.10</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>c.11</td>
<td></td>
<td>Choose the most likely reason for deviation between predicted and measured design performance</td>
</tr>
<tr>
<td>c.12</td>
<td></td>
<td>Justify the choice?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Formulate a method to validate the explanation for deviation between predicted and measured</td>
</tr>
<tr>
<td></td>
<td></td>
<td>design performance?</td>
</tr>
</tbody>
</table>

No. of Attributes: 10
### Outcome (e): an ability to identify, formulate, and solve engineering problems

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
<th>Poor</th>
<th>Fair</th>
<th>Adequate</th>
<th>Good</th>
<th>V. Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.1</td>
<td>Read and understand the information given about a problem?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.2</td>
<td>Define a problem in ways you can understand it (build up a clear picture in your mind of the different parts of the problem and the significance of each part)?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>e.3</td>
<td>Research and gather information pertaining to the problem?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>e.4</td>
<td>Use a process, as well as a variety of tactics and approaches to tackle (real world) problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.5</td>
<td>Monitor your problem-solving process and occasionally reflect upon its effectiveness?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.6</td>
<td>Focus on accuracy rather than speed when you solve problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.7</td>
<td>Write down ideas, create charts / figures to help overcome the storage limitations of short-term memory (where problem-solving takes place).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>e.8</td>
<td>Be organized and systematic when you solve problems?</td>
<td></td>
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</tr>
<tr>
<td>e.9</td>
<td>Be flexible in the application of a problem-solving strategy (keep options open, view a situation from many different perspectives / points of view)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.10</td>
<td>Draw on the pertinent subject knowledge and critically assess the quality and accuracy of that knowledge / data?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.11</td>
<td>Take risks, cope with ambiguity, welcome change and manage stress, when you solve problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.12</td>
<td>Use an overall approach that emphasizes fundamentals rather than trying to combine various memorized sample solutions?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

No. of Attributes: 12

### Outcome (g): an ability to communicate effectively

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
<th>Poor</th>
<th>Fair</th>
<th>Adequate</th>
<th>Good</th>
<th>V. Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>g.1</td>
<td>Produce well-organized reports, following guidelines?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.2</td>
<td>Use clear and correct language and terminology while describing experiments, projects, or solutions to engineering problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.3</td>
<td>Describe accurately in a few paragraphs a project / experiment performed, the procedure used, and the most important results when writing abstracts or summaries?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.4</td>
<td>Give well-organized presentations, following guidelines?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.5</td>
<td>Use visuals to convey their message effectively, when making presentations?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.6</td>
<td>Present the most important information about a project / experiment, while staying within my allotted time when making presentations?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. of Attributes: 6
### Outcome (j): a knowledge of contemporary issues

<table>
<thead>
<tr>
<th>No. of Attributes</th>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>j.1</td>
<td></td>
<td>Identify contemporary issues (ex. bioethics, market and workforce globalization, mobile technology and communications, information management and security) and explain what makes them particularly problematic or controversial in the present time?</td>
</tr>
<tr>
<td></td>
<td>j.2</td>
<td></td>
<td>Suggest reasonable theories regarding the root cause(s) of contemporary problems?</td>
</tr>
<tr>
<td></td>
<td>j.3</td>
<td></td>
<td>Identify possible solutions to contemporary problems, as well as any limitations of such strategies?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of Attributes: 3</td>
</tr>
</tbody>
</table>

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.

### Outcome (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

<table>
<thead>
<tr>
<th>No. of Attributes</th>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>k.1</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>k.2</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>k.3</td>
<td></td>
<td>Perform web-based research?</td>
</tr>
<tr>
<td></td>
<td>k.4</td>
<td></td>
<td>Use Word and Excel to produce high quality technical reports?</td>
</tr>
<tr>
<td></td>
<td>k.5</td>
<td></td>
<td>Use Power Point to give high quality oral presentations?</td>
</tr>
<tr>
<td></td>
<td>k.6</td>
<td></td>
<td>Use computer simulations to conduct parametric studies?</td>
</tr>
<tr>
<td></td>
<td>k.7</td>
<td></td>
<td>Use computer simulations to perform optimization?</td>
</tr>
<tr>
<td></td>
<td>k.8</td>
<td></td>
<td>Use computer simulations to perform 'what if' explorations?</td>
</tr>
<tr>
<td></td>
<td>k.9</td>
<td></td>
<td>Use state-of-the-art technology for engineering system design, control, and analysis?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of Attributes: 7</td>
</tr>
</tbody>
</table>

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.
### Course Evaluation Survey

**Department of Aeronautical Engineering**  
Indirect Assessment of Program Outcomes  
Course Evaluation Survey  

**Course (AE-311) - Section (01) - Semester (Spring) - Year 2008/2009**

Please complete this questionnaire and tick the box that is most appropriate to your answer. This will help us to improve the service we provide to you and other students. Your answers and comments are confidential.

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Somewhat</th>
<th>Moderately</th>
<th>Reasonably</th>
<th>Highly</th>
<th>Ext. highly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Course Objectives were clear to me</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>The Course was beneficial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Resources/facilities (equipment, classroom, lab, etc) were satisfactory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>The textbook was beneficial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Lectures were well planned and well executed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>The assessment of the course work was reasonable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Timing to submit the course work was suitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Overall, I recommend other students to take this course</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The most interesting subject was:

Please list some positive aspects of this course:

1:

2:

3:

4:

5:

Please list items that could be improved in the following course offering:

1:

2:

3:

4:

5:
### CLOs Survey

**Upon the completion of this course how do you rank your ability to do the following:**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Derive the general governing equations from the fundamental principles.</td>
</tr>
<tr>
<td>1.2</td>
<td>State the assumptions for incompressible potential flow and use them to simplify the general equations.</td>
</tr>
<tr>
<td>2.1</td>
<td>Define vorticity and circulation and distinguish between rotational and irrotational flows.</td>
</tr>
<tr>
<td>2.2</td>
<td>Define and compute stream function, streamlines, potential function, equipotential lines for a flow and calculate each, if they exist.</td>
</tr>
<tr>
<td>2.3</td>
<td>State and implement the general approach for the solution of incompressible potential flow.</td>
</tr>
<tr>
<td>2.4</td>
<td>Analyze (i.e., calculate velocities, pressures, stream function, potential function, stagnation points, streamlines, equipotential lines, circulation around bodies, etc.) the elementary flows (uniform, source/sink, ...)</td>
</tr>
<tr>
<td>2.5</td>
<td>Implement the source panel method to compute pressure and velocity on non-lifting surfaces.</td>
</tr>
<tr>
<td>2.6</td>
<td>State Kutta-Joukowski Theorem and use it to compute lift.</td>
</tr>
<tr>
<td>3.1</td>
<td>Explain and apply the Kutta Condition for any sharp edge of a wing (i.e., what it means physically and how it is enforced mathematically.)</td>
</tr>
<tr>
<td>3.2</td>
<td>State Kelvin’s theorem and explain how it is implemented to setup the vortex system of an airfoil.</td>
</tr>
<tr>
<td>3.3</td>
<td>Derive the fundamental equation of Thin Airfoil Theory.</td>
</tr>
<tr>
<td>3.4</td>
<td>Use thin airfoil theory to compute aerodynamic characteristics of airfoils (lift and drag at various angles of attack, pitching moment about various points, a.c. location, c.p. location, etc.).</td>
</tr>
<tr>
<td>3.5</td>
<td>Describe and implement the vortex panel method to compute aerodynamic characteristics for thick airfoils.</td>
</tr>
<tr>
<td>3.6</td>
<td>Describe qualitatively and quantitatively both laminar and turbulent boundary layers in terms of their thickness, velocity profiles and shear stress variation along a surface.</td>
</tr>
<tr>
<td>3.7</td>
<td>Use the Boundary Layer Theory to calculate the skin friction drag, estimate the pressure drag of bodies, and predict location on the surface where boundary layer separation is likely to occur.</td>
</tr>
<tr>
<td>3.8</td>
<td>Describe the aerodynamic characteristics of airfoils and their impact on airfoil design.</td>
</tr>
<tr>
<td>3.9</td>
<td>Use software packages (JavaFoil) to investigate the effects of thickness and camber on the aerodynamic characteristics (lift slope, aerodynamic center) of airfoils.</td>
</tr>
<tr>
<td>3.10</td>
<td>Use software packages (JavaFoil) to investigate the effects of airfoil geometrical characteristics and the angle of attack on the boundary layer behavior and how it is related to changes in lift and drag.</td>
</tr>
<tr>
<td>4.1</td>
<td>Describe the flow field around wings of finite span and Explain the generation of induced drag.</td>
</tr>
<tr>
<td>4.2</td>
<td>Describe Prandtl’s lifting-line theory and state its limitations.</td>
</tr>
<tr>
<td>4.3</td>
<td>Apply the results from Prandtl’s lifting-line theory to calculate the aerodynamic characteristics of airplane wings.</td>
</tr>
<tr>
<td>4.4</td>
<td>Identify wing aerodynamic parameters and recognize their impact on wing design.</td>
</tr>
<tr>
<td>4.5</td>
<td>Describe and implement (through the software package TORNADO) the Vortex Lattice Method to compute aerodynamic characteristics of wings and wing-tip-canard configurations (including high-lift device configurations).</td>
</tr>
<tr>
<td>5.1</td>
<td>List several examples of regional, national, and/or global contemporary problems related to aerodynamics (ex. environmental issues, natural resources and energy conservation, etc.) articulate a problem/position</td>
</tr>
<tr>
<td>5.2</td>
<td>Identify possible solutions to these problems, as well as any limitations of these solutions.</td>
</tr>
</tbody>
</table>

---

**Course Level Indirect Assessment**

**Students’ Survey for Course Learning Objectives and Instructional Tools**

**COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009**

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Fair</td>
<td>Adequate</td>
<td>Good</td>
<td>V. Good</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
2.2 Direct Course Assessment Tolls
Blank Copies of Direct Assessment Tools (Exams, HW, Assignment or Project Statements, etc.), are to be inserted here
### 2.3 Results of Class Direct Assessment tolls

#### RESULTS OF ALL GRADED ASSESSMENTS TOOLS

<table>
<thead>
<tr>
<th>CLASS</th>
<th>GRADED ASSESSMENT TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>#1</td>
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#### DEPARTMENT OF Aeronautical Engineering
Course Level Indirect Assessment
Students' Survey for Course Learning Objectives and Instructional Tools

COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009

#### CLASS INDIRECT ASSESSMENT OF COURSE LEARNING OBJECTIVES & INSTRUCTIONAL TOOLS

![Evaluation of Course Learning Objectives](image1)

![Evaluation of Course Learning Objectives](image2)

---

2.7
## COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009

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## CLASS ASSESSMENT OF PROGRAM OUTCOMES

### DIRECT vs INDIRECT

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### ACHIEVEMENT OF PROGRAM OUTCOMES BY THE STUDENTS WHO PASSED THE COURSE

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### PASSING STUDENTS AVERAGE

#### PROGRAM OUTCOMES

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#### PROGRAM OUTCOMES

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## Direct Assessment

### Number of Students Who Passed the Course

- The number of students who passed the course is **5 out of 10**.

### Program Outcomes (P.O.)

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### List of the Students Who Passed the Course

- The number of students who passed the course is **5 out of 10**.

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2.4 Results of Class Indirect Assessment of Programs Outcomes

INDIRECT ASSESSMENT OF PROGRAM OUTCOMES

PROGRAM OUTCOMES

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INDIRECT ASSESSMENT

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<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
<th>l</th>
</tr>
</thead>
<tbody>
<tr>
<td>57%</td>
<td>86%</td>
<td>NA</td>
<td>29%</td>
<td>NA</td>
<td>67%</td>
<td>NA</td>
<td>43%</td>
<td>NA</td>
<td>43%</td>
<td>NA</td>
<td>43%</td>
<td>NA</td>
</tr>
<tr>
<td>AVERAGE CONFIDENCE LEVEL (CONFIDENCE LEVEL ON A &quot;0 TO 5&quot; SCALE)</td>
<td>2.8</td>
<td>NA</td>
<td>4.0</td>
<td>NA</td>
<td>2.7</td>
<td>NA</td>
<td>3.0</td>
<td>NA</td>
<td>3.0</td>
<td>NA</td>
<td>3.0</td>
<td>NA</td>
</tr>
<tr>
<td>AVERAGE CONFIDENCE LEVEL (%)</td>
<td>79%</td>
<td>NA</td>
<td>54%</td>
<td>NA</td>
<td>59%</td>
<td>NA</td>
<td>59%</td>
<td>NA</td>
<td>59%</td>
<td>NA</td>
<td>59%</td>
<td>NA</td>
</tr>
</tbody>
</table>
2.5 End of Semester Cos Assessment Report

COURSE( AE-311 ) - SECTION ( 01 ) - SEMESTER ( Spring ) - YEAR 2008 /2009

END OF SEMESTER ASSESSMENT REPORT OF COURSE LEARNING OBJECTIVES

Prepared by: Dr. Ibraheem AL-Qadi

| LO.1 | LO.2 | LO.3 | LO.4 | LO.5 | LO.6 | LO.7 | LO.8 | LO.9 | LO.10 | LO.11 | LO.12 | LO.13 | LO.14 | LO.15 | LO.16 | LO.17 | LO.18 | LO.19 | LO.20 |
|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 100%| 100%| 40%  | 20%  | 30%  | 90%  | 90%  | 60%  | 60%  | 30%   | 70%   | 70%   | 60%   | 60%   | 60%   | 40%   | 60%   | 50%   | 100%  | 100%  |

| LO.21 | LO.22 | LO.23 | LO.24 | LO.25 | LO.26 | LO.27 | LO.28 | LO.29 | LO.30 | LO.31 | LO.32 | LO.33 | LO.34 | LO.35 | LO.36 | LO.37 | LO.38 | LO.39 | LO.40 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 30%   | 40%   | 100%  | 60%   | 90%   | 20%   | 40%   | 60%   | 60%   | 30%   | 70%   | 60%   | 30%   | 60%   | 40%   | 60%   | 50%   | 100%  | 100%  | 100%  |

| LO.21 | LO.22 | LO.23 | LO.24 | LO.25 | LO.26 | LO.27 | LO.28 | LO.29 | LO.30 | LO.31 | LO.32 | LO.33 | LO.34 | LO.35 | LO.36 | LO.37 | LO.38 | LO.39 | LO.40 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 62%   | 50%   | 42%   | 60%   | 42%   | 42%   | 60%   | 42%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   | 60%   |

| Passing Criteria | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  |


| LO.21 | LO.22 | LO.23 | LO.24 | LO.25 | LO.26 | LO.27 | LO.28 | LO.29 | LO.30 | LO.31 | LO.32 | LO.33 | LO.34 | LO.35 | LO.36 | LO.37 | LO.38 | LO.39 | LO.40 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|

| INSTRUCTOR'S COMMENTS ON ALL RED CELLS (Perceived Problems) ABOVE |

<table>
<thead>
<tr>
<th>Learning Object</th>
<th>Perceived Problems</th>
<th>Comments</th>
<th>Actions to be taken</th>
</tr>
</thead>
</table>

2.11
### 2.6 End of Semester Outcomes Assessment Report

**COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009**

**END OF SEMESTER ASSESSMENT REPORT OF COURSE - ADDRESSED PROGRAM OUTCOMES**

**Prepared by:** Dr. Ibraheem Al-Qadi

<table>
<thead>
<tr>
<th>DIRECT ASSESSMENT</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
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<th>m</th>
<th>n</th>
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<tbody>
<tr>
<td>Outcome Passing Criteria</td>
<td>0.8</td>
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<td>0.8</td>
<td>NA</td>
<td>0.8</td>
<td>NA</td>
<td>0.8</td>
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<td>NA</td>
<td>0.8</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>% Students Exceeding Criteria</td>
<td>50%</td>
<td>42%</td>
<td>NA</td>
<td>32%</td>
<td>50%</td>
<td>20%</td>
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<td>42%</td>
<td>5%</td>
<td>42%</td>
</tr>
<tr>
<td>Class Average (of All Students)</td>
<td>52%</td>
<td>52%</td>
<td>NA</td>
<td>52%</td>
<td>52%</td>
<td>52%</td>
<td>52%</td>
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<td>52%</td>
<td>52%</td>
</tr>
<tr>
<td>Class Average (of Passing Students)</td>
<td>65%</td>
<td>56%</td>
<td>NA</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
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</tr>
<tr>
<td>Perceived Problems</td>
<td>Problem</td>
<td>Problem</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>INDIRECT ASSESSMENT</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
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<th>n</th>
<th>o</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome Passing Criteria (out of 10)</td>
<td>3</td>
<td>NA</td>
<td>3</td>
<td>NA</td>
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<td>3</td>
<td>NA</td>
<td>3</td>
<td>NA</td>
<td>3</td>
<td>NA</td>
<td>3</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>% Students Exceeding Criteria</td>
<td>52%</td>
<td>52%</td>
<td>NA</td>
<td>52%</td>
<td>52%</td>
<td>52%</td>
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<td>52%</td>
</tr>
<tr>
<td>Class Average (out of 10)</td>
<td>2.8</td>
<td>NA</td>
<td>2.8</td>
<td>NA</td>
<td>2.8</td>
<td>NA</td>
<td>2.8</td>
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<td>2.8</td>
<td>NA</td>
<td>2.8</td>
</tr>
<tr>
<td>Perceived Problems</td>
<td>Problem</td>
<td>Problem</td>
<td>Problem</td>
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<td>Problem</td>
</tr>
</tbody>
</table>

**INSTRUCTOR'S COMMENTS ON ALL RED CELLS (if Perceived Problems) ABOVE**

<table>
<thead>
<tr>
<th>Program</th>
<th>Previous Offering</th>
<th>Present Offering</th>
<th>Perceived Problems</th>
<th>Comments</th>
<th>Actions to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome</td>
<td>% St. Exceeding</td>
<td>Class Act with St.</td>
<td>Class Av. Pass St.</td>
<td>Exposure</td>
<td>The level of students' performance in this semester is very low. 50% passed the course with 70% grade or less.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1. Homework: Most the students do not take homework seriously and some of them end up copying from classmates. This reflects on their performance in exams.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Final Exam: most students perform poorly on the final exam and with its 40% of grade. This results in a high failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Major Exam (45%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Design Project (20%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>An article about contemporary issues (10%)</td>
</tr>
</tbody>
</table>

2.12
Supported Program Outcomes (a)
3.1 Outcome Definition and Outcome Indicators

Outcome (a): an ability to apply knowledge of mathematics, science, and engineering

a.1 Use Math, Science, and Engineering Fundamentals to formulate the problem and devise appropriate solution strategies.

a.2 Consistently implement solution strategy and get correct answers.

a.3 Apply engineering judgment to evaluate answers.

3.2 Course Learning Objectives addressing the outcome
## 3.3 Outcome Survey

### Outcome (a): an ability to apply knowledge of mathematics, science, and engineering

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABLE</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.1</td>
<td></td>
<td>Apply mathematics in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.2</td>
<td></td>
<td>Apply calculus (differentiation, integration, etc.) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.3</td>
<td></td>
<td>Use differential equations in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.4</td>
<td></td>
<td>Use linear algebra (matrices, systems of equations, etc.) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.5</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>a.6</td>
<td></td>
<td>Apply equilibrium principles and Newton’s laws (including free-body diagrams) in the solution of engineering problems?</td>
</tr>
<tr>
<td>a.7</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>a.8</td>
<td></td>
<td>Apply physics concepts (friction, thermal / fluid concepts etc.) in the solution of engineering</td>
</tr>
</tbody>
</table>

| No. of Attributes   | 6          |

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.
3.4 Outcome Assessment and Improvement Report
3.5  Students Work Samples
### Assessment Rubrics for Program Outcomes

#### Outcome (c): The artifact demonstrates the student’s ability to identify, formulate, and solve engineering problems

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Poorly identifies relevant information but may start with extensive data.</td>
<td>Cannot identify and assemble relevant information.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The problem is approached and modeled as a logical and technically correct fashion.</td>
<td>Student cannot consistently and efficiently apply engineering principles. No conceptual errors appear. Few if any procedural errors exist. Student appears to be aware of all steps.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The absence of necessary information is recognized and reasonable approximations are made.</td>
<td>Consistently identifies relevant information but may start with extensive data.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Clear Solution Procedure.</td>
<td>Presenta step-to-step solution that is logical and adequately detailed. Most of the steps are understandable, some steps lack detail or are confusing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. The problem solution is usually correct and always reasonable.</td>
<td>Has no more than one, if any, unrecognized implausible answers.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

*King Abdullah University*

*College of Engineering*

*Academic Accreditation Unit*

*Assessment Rubrics for Program Outcomes*

---

*Outcome (c): The artifact demonstrates the student’s ability to identify, formulate, and solve engineering problems*

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Poorly identifies relevant information but may start with extensive data.</td>
<td>Cannot identify and assemble relevant information.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The problem is approached and modeled as a logical and technically correct fashion.</td>
<td>Student cannot consistently and efficiently apply engineering principles. No conceptual errors appear. Few if any procedural errors exist. Student appears to be aware of all steps.</td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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*King Abdullah University*

*College of Engineering*

*Academic Accreditation Unit*

*Assessment Rubrics for Program Outcomes*
King AbdulAZIZ University
Faculty of Engineering
Aeronautical Engineering Department

AE-311: Incompressible Aerodynamics

Spring 2008
1st Major EXAM

TIME ALLOWED 90 MIN.

Student's Name: Rayyan Salih Arman Alkim
University I.D.#: 0456289

<table>
<thead>
<tr>
<th>Problem #</th>
<th>1 30%</th>
<th>2 30%</th>
<th>3 20%</th>
<th>4 20%</th>
<th>Total 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>25%</td>
<td>20%</td>
<td>5%</td>
<td>15%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Rules:
- Answer All Questions.
- The exam is closed book! so no documents are allowed.
- Be clear and organized.
30% Problem #1:
(a) Derive the integral form of the continuity equation using Eulerian Approach (fixed control volume concept).
(b) State the assumptions for incompressible potential flow and use them to simplify the equation obtained in (b).
(c) Define Vorticity.
(d) Define Circulation.
(e) What is the difference between rotational and irrotational flow.
(f) State the general approach for the solution of incompressible potential flow.

30% Problem #2:
How would you model the 2D irrotational flow shown in figure 2?
(a) Name and sketch the elementary flows.
(b) Find \( q(x) \) along the wall.

20% Problem #3:
The stream function of a low-speed two-dimensional flow is given by:
\[ \psi = 2x + 5y - 7 \tan^{-1} \left( \frac{y}{x} \right). \]
(a) Show that the stream function describes an irrotational flow.
(b) Find the volume flow between the two points (1,1) and (2,2).
(c) If the pressure at the origin is 6 bars and the density is 1.2 kg/m³, find the pressure at the point (1,2).
(d) Find the expression for the velocity potential.

20% Problem #4:
The components of \( \vec{F} \) are given by
\[ u = x^2 - y^2, \quad v = -2xy. \]
(a) Is the flow a possible physical incompressible flow?
(b) Is the flow irrotational?
(c) Find the value of the integral of the component of \( \vec{F} \) along a straight line between the points (0, 0) and (1, 2).
(d) If the path of integration between the two points is a parabola instead of a straight line, Does the value of the integral change or not and why?
Elementary flows

Uniform Flow:
\[ \psi = \nu y - v x \]
\[ \phi = u x + v y \]

Source-sink flow:
\[ \psi = \frac{\Lambda}{2\pi} \theta \]
\[ \phi = \frac{\Lambda}{2\pi} \ln \left( \frac{r}{r_0} \right) \]

Vortex flow:
\[ \psi = \frac{\Gamma}{2\pi} \ln \left( \frac{r}{r_0} \right) \]
\[ \phi = \frac{\Gamma}{2\pi} \theta \]

Doublet flow:
\[ \psi = \frac{\kappa}{2\pi} \sin \theta \]
\[ \phi = \frac{\kappa}{2\pi} \cos \theta \]

Relation between velocity and \( \psi \) & \( \phi \):
\[ u = \frac{\partial \psi}{\partial y}, \quad v = -\frac{\partial \psi}{\partial x}, \quad u = \frac{\partial \phi}{\partial x}, \quad v = -\frac{\partial \phi}{\partial y} \]
\[ u_x = \frac{1}{r} \frac{\partial \psi}{\partial \theta}, \quad u_y = -\frac{\partial \psi}{\partial r}, \quad u_x = \frac{\partial \phi}{\partial r}, \quad u_y = \frac{1}{r} \frac{\partial \phi}{\partial \theta} \]

Continuity Equation:
\[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \]
\[ \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{1}{r} \frac{\partial u}{\partial \theta} = 0 \]
\[ \frac{\partial \phi}{\partial r} + \frac{1}{r} \frac{\partial \phi}{\partial \theta} = 0 \]
\[ \frac{\partial \phi}{\partial r} + \frac{1}{r} \frac{\partial \phi}{\partial \theta} + \frac{1}{r^2} \frac{\partial^2 \phi}{\partial \theta^2} = 0 \]

Vorticity Equation:
\[ \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = \frac{\xi}{2} \]
\[ \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{1}{r} \frac{\partial u}{\partial \theta} = \frac{\xi}{2} \]
\[ \frac{\partial \psi}{\partial r} + \frac{1}{r} \frac{\partial \psi}{\partial \theta} + \frac{1}{r^2} \frac{\partial^2 \psi}{\partial \theta^2} = \frac{\xi}{2} \]
\[ \frac{\partial \psi}{\partial r} + \frac{1}{r} \frac{\partial \psi}{\partial \theta} + \frac{1}{r^2} \frac{\partial^2 \psi}{\partial \theta^2} = \frac{\xi}{2} \]
TRIGONOMETRY
Trigonometric functions are defined using a right triangle.

\[ \sin \theta = \frac{y}{r}, \cos \theta = \frac{x}{r}, \tan \theta = \frac{y}{x} \]

\[ \csc \theta = \frac{1}{\sin \theta}, \sec \theta = \frac{1}{\cos \theta}, \cot \theta = \frac{1}{\tan \theta} \]

Law of Sines
\[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \]

Law of Cosines
\[ a^2 = b^2 + c^2 - 2bc \cos A \]
\[ b^2 = a^2 + c^2 - 2ac \cos B \]
\[ c^2 = a^2 + b^2 - 2ab \cos C \]

Identities
\[ \sin^2 \theta + \cos^2 \theta = 1 \]
\[ \tan \theta \cot \theta = 1 \]
\[ \sin(\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta \]
\[ \cos(\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta \]
\[ \sin 2\alpha = 2 \sin \alpha \cos \alpha \]
\[ \cos 2\alpha = \cos^2 \alpha - \sin^2 \alpha = 1 - 2 \sin^2 \alpha = 2 \cos^2 \alpha - 1 \]
\[ \tan 2\alpha = \frac{2 \tan \alpha}{1 - \tan^2 \alpha} \]
\[ \cot(\alpha + \beta) = \frac{\cot \alpha \cot \beta - 1}{\cot \alpha + \cot \beta} \]
\[ \cot(\alpha - \beta) = \frac{\cot \alpha \cot \beta + 1}{\cot \alpha - \cot \beta} \]
\[ \sin(\alpha + \beta) = \sqrt{1 - \cos^2 \alpha} \sqrt{1 - \cos^2 \beta} \]
\[ \cos(\alpha + \beta) = \frac{\cos \alpha \cos \beta - \sin \alpha \sin \beta}{\cos \alpha \cos \beta + \sin \alpha \sin \beta} \]
\[ \sin(\alpha - \beta) = \sqrt{1 - \cos^2 \alpha} \sqrt{1 + \cos^2 \beta} \]
\[ \cos(\alpha - \beta) = \frac{\cos \alpha \cos \beta + \sin \alpha \sin \beta}{\cos \alpha \cos \beta - \sin \alpha \sin \beta} \]

\[ \sin(2\alpha) = \pm \sqrt{1 - \cos^2 \alpha} \]
\[ \cos(2\alpha) = \frac{1 - \cos^2 \alpha}{\sqrt{1 - \cos^2 \alpha}} \]
\[ \tan(2\alpha) = \pm \sqrt{1 - \cos^2 \alpha} \]
\[ \cot(2\alpha) = \pm \sqrt{1 + \cos^2 \alpha} \]

\[ \sin \alpha \sin \beta = \frac{1}{2} \left[ \cos(\alpha - \beta) - \cos(\alpha + \beta) \right] \]
\[ \cos \alpha \cos \beta = \frac{1}{2} \left[ \cos(\alpha - \beta) + \cos(\alpha + \beta) \right] \]
\[ \sin \alpha \cos \beta = \frac{1}{2} \left[ \sin(\alpha + \beta) + \sin(\alpha - \beta) \right] \]
\[ \cos \alpha \sin \beta = \frac{1}{2} \left[ \sin(\alpha + \beta) - \sin(\alpha - \beta) \right] \]

COMPLEX NUMBERS
Definition \( i = \sqrt{-1} \)
\[ (a + ib) + (c + id) = (a + c) + i(b + d) \]
\[ (a + ib) - (c + id) = (a - c) + i(b - d) \]
\[ (a + ib)(c + id) = (ac - bd) + i(ad + bc) \]
\[ \frac{a + ib}{c + id} = \frac{(ac + bd) + i(bc - ad)}{c^2 + d^2} \]
\[ e^{i\theta} = \cos \theta + i \sin \theta \]
\[ e^{-i\theta} = \cos \theta - i \sin \theta \]

Euler’s Identity
\[ e^{i\theta} = \cos \theta + i \sin \theta \]
\[ e^{2i\theta} = \cos 2\theta + i \sin 2\theta \]

Roots
If \( k \) is any positive integer, any complex number (other than zero) has \( k \) distinct roots. The \( k \) roots of \( e^{i\theta} \) can be found by substituting successively \( n = 0, 1, 2, ..., (k-1) \) in the formula.
\[ w = \sqrt[k]{e^{i\frac{\theta + 360^\circ}{k}} + i \sin \left( \frac{\theta + 360^\circ}{k} \right)} \]

MATRICES
A matrix is an ordered rectangular array of numbers with \( m \) rows and \( n \) columns. The element \( a_{ij} \) refers to row \( i \) and column \( j \).
DERIVATIVES AND INDEFINITE INTEGRALS

In these formulas, u, v, and w represent functions of x. Also, a, c, and n represent constants. All arguments of the trigonometric functions are in radians. A constant of integration should be added to the integrals. To avoid terminology difficulty, the following definitions are followed: arcus u = sin⁻¹ u, (sin u)² = (1 - cos u).
1. \( f'(x) = f(x) \)
2. \( \frac{d}{dx} x^a = ax^{a-1} \)
3. \( \frac{d}{dx} \cos(x) = -\sin(x) \)
4. \( \frac{d}{dx} \sin(x) = \cos(x) \)
5. \( \frac{d}{dx} e^{ax} = ae^{ax} \)
6. \( \frac{d}{dx} a^x = a^x \ln a \)
7. \( \frac{d}{dx} \ln x = \frac{1}{x} \)
8. \( \frac{d}{dx} \tan x = \sec^2 x \)
9. \( \frac{d}{dx} \sec x = \sec x \tan x \)
10. \( \frac{d}{dx} \cot x = -\csc^2 x \)
11. \( \frac{d}{dx} \csc x = -\csc x \cot x \)
12. \( \frac{d}{dx} \tan^{-1} x = \frac{1}{1+x^2} \)
13. \( \frac{d}{dx} \sec^{-1} x = \frac{1}{x \sqrt{x^2 - 1}} \)
14. \( \frac{d}{dx} \csc^{-1} x = \frac{1}{x \sqrt{x^2 - 1}} \)

\[ \int f(x) \, dx = F(x) + C \]
\[ \int a \, f(x) \, dx = a \int f(x) \, dx \]
\[ \int [u(x) \pm v(x)] \, dx = \int u(x) \, dx \pm \int v(x) \, dx \]
\[ \int e^{ax} \, dx = \frac{e^{ax}}{a} + C \]
\[ \int a(x) \, dv(x) = a(x)v(x) - \int v(x) \, da(x) \]
\[ \int \frac{dx}{ax + b} = \frac{1}{a} \ln |ax + b| \]
\[ \frac{dx}{\sqrt{a^2 - x^2}} = \frac{1}{a} \sin^{-1} \left( \frac{x}{a} \right) + C \]
\[ \frac{dx}{\sqrt{x^2 - a^2}} = \ln \left| x + \sqrt{x^2 - a^2} \right| + C \]
\[ \frac{dx}{\sqrt{a^2 - x^2}} = \sin^{-1} \left( \frac{x}{a} \right) + C \]
\[ \frac{dx}{\sqrt{x^2 - a^2}} = \ln \left| x + \sqrt{x^2 - a^2} \right| + C \]
Problem 3

a) Continuity Eq --

- Mass can be neither nor destroyed (absence in rectangular nucl.
- Consider: The C.V fixed
  in space and fluid
  can enter in and leave the
  C.V
  C.V is fixed

Net mass flow out of C.V = time rate of decrease of
mass flow inside C.V

- Time rate of decrease of mass flow inside C.V:
  \[ \frac{d}{dt} \iiint \rho \mathbf{v} \, dV \]
  and when C.V is fixed in space we can write
  \[ \iiint \frac{\partial \rho}{\partial t} \mathbf{v} \, dV \]

Net mass flow out of C.V through \( S \) = \( \iiint \rho \mathbf{v} \cdot n \, dS \)

Substitute \( 2 \) & \( 3 \) in \( 1 \)

\[ \iiint \rho \mathbf{v} \cdot n \, ds = -\iiint \frac{\partial \rho}{\partial t} \mathbf{v} \, dV \]

The Eq. \( 4 \) is Continuity Equation of Integral Form.
b) By Using Divergence Therem:

$$\iiint \rho \cdot \nabla \cdot \mathbf{v} \, dv = \iiint \mathbf{v} \cdot (\rho \mathbf{v}) \, dv$$

From (4):

$$\iiint \mathbf{v} \cdot (\rho \mathbf{v}) \, dv = - \iiint \frac{\partial \rho}{\partial t} \mathbf{v} \cdot dv$$

$$= \iiint (\nabla \cdot (\rho \mathbf{v}) + \frac{\partial \rho}{\partial t} \mathbf{v}) \, dv$$

since the abbreviating C.V is shaped, the By will be zero.

$$\iiint (\nabla \cdot (\rho \mathbf{v}) + \frac{\partial \rho}{\partial t} \mathbf{v}) \, dv = 0$$

- For steady flow, the time derivative

$$\frac{\partial \rho}{\partial t} \mathbf{v} = 0$$

- For Incompressible flow, $\rho$ is constant:

$$\nabla \cdot \mathbf{v} = 0$$

c) Vorticity: its measure of rotational flow and its twice of angular velocity

$$\mathbf{S} = \nabla \times \mathbf{v}$$

d) Circulation: The negative line of the integral of the around velocity in the close curve of the flow

$$\Gamma = - \oint \mathbf{v} \cdot ds$$
e) \[ \mathbf{S} = 0 \implies \text{The flow is irrotational flow and Viscous flow} \]

\[ \mathbf{S} \neq 0 \implies \text{The flow is rotational flow and Inviscid flow} \]

f) Continuity Eq: \[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \quad \nabla \cdot \mathbf{v} = 0 \]

Vorticity Eq: \[ \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = 0, \quad \nabla \cdot \mathbf{\omega} = 0 \]

Momentum Eq: \[ u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = - \frac{1}{\rho} \frac{\partial p}{\partial x} \]

\[ u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = - \frac{1}{\rho} \frac{\partial p}{\partial y} \]

Problem 2 \[ \Psi = \psi_{\text{vortex}} + \psi_{\text{sink}} \]

\[ \psi_{\text{vortex}} = \frac{\Gamma}{4\pi} \ln \left( \frac{r^2}{r_0^2} \right) \]

\[ + \sin k = \pm \frac{A}{2\pi} \cos (\theta_2 - \theta_1) \]

\[ \psi = -\frac{\Gamma}{4\pi} \ln \left( \frac{r^2}{r_0^2} \right) + \frac{A}{2\pi} \cos (\theta_2 - \theta_1) \]

\[ \psi_{\text{vortex}} = \frac{\Gamma}{4\pi} \ln \left( \frac{r^2}{r_0^2} \right) \]

\[ = \frac{\Gamma}{4\pi} \ln \left( \frac{(y-H)^2 + x^2}{(y+H)^2 + x^2} \right) \]

\[ = \frac{\Gamma}{4\pi} \ln \left( \frac{x^2 + (y-H)^2}{x^2 + (y+H)^2} \right) \]

\[ \psi_{\text{sink}} = -\frac{A}{2\pi} (\theta_1 + \theta_2) = -\frac{A}{2\pi} \left( \tan^{-1} \frac{y-H}{x} + \tan^{-1} \frac{y+H}{x} \right) \]

\[ u = \frac{\partial \psi}{\partial y} = \frac{\partial \psi_{\text{sink}}}{\partial y} = \frac{\partial \psi_{\text{vortex}}}{\partial y} \]

\[ \text{at} \quad \theta = 0 \implies \frac{\partial \psi_{\text{sink}}}{\partial y} = \frac{\partial \psi_{\text{vortex}}}{\partial y} = \frac{\partial \psi}{\partial y} = \frac{\partial u}{\partial y} = 0 \]

\[ \frac{\partial \psi}{\partial y} = 0 \implies \frac{\partial (u^2 + v^2)}{\partial y} = 0 \implies 1 - \left( \frac{u^2 + v^2}{V_0^2} \right) = 1 - \left( \frac{V_0^2}{V_0^2} \right) \]

\[ V_0 \quad \text{is the speed of sound} \]

\[ C_p = 1 - \left( \frac{u^2 + v^2}{V_0^2} \right) \]

\[ \text{At} \quad V = 0 \implies \frac{\partial \psi}{\partial y} = 0 \]

\[ \frac{\partial \psi}{\partial y} = 0 \implies \frac{\partial (u^2 + v^2)}{\partial y} = 0 \implies 1 - \left( \frac{u^2 + v^2}{V_0^2} \right) = 1 - \left( \frac{V_0^2}{V_0^2} \right) \]

\[ V_0 \quad \text{is the speed of sound} \]

\[ C_p = 1 - \left( \frac{u^2 + v^2}{V_0^2} \right) \]
Problem 3 \[ \psi = 2x + 5y - 7 \tan^{-1} \left( \frac{y}{x} \right) \]

(b) Irrotational flow: \[ \mathbf{v} = \frac{\partial \psi}{\partial y} - \frac{\partial \psi}{\partial x} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \]
\[ \frac{\partial \psi}{\partial x} = 2 - 7 \left( \frac{1}{x^2 + y^2} \right) \] \[ \frac{\partial \psi}{\partial y} = 5 - 7 \left( \frac{1}{x^2 + y^2} \right) \]

The flow is irrotational (equal \( \nabla \times \mathbf{v} \))

\[ \psi_{Po} = \int_{op} \mathbf{v} \cdot d\mathbf{v} \Rightarrow \int \left( \mathbf{v} \cdot \mathbf{v} \right) dV \]

(c) Using Bernoulli Eqn:

\[ \text{Pressure} = -\int \mathbf{P} \cdot d\mathbf{s} = -\int (\mathbf{v} \cdot \mathbf{P}) dV = -\int (\nabla \cdot \mathbf{v}) dV \]
\[ \nabla \cdot \mathbf{P} = \frac{\partial P}{\partial x} + \frac{\partial P}{\partial y} \]

d) \[ \psi_{Po} = \int_{op} \mathbf{u} \cdot d\mathbf{v} \]
\[ \mathbf{v} = u + v \]
\[ u = \frac{\partial \psi}{\partial y} = 5 - 7 \left( \frac{1}{x^2 + y^2} \right) \]
a) Incompressible flows: (Continuity Eq)
\[ \frac{\partial u}{\partial x} = 2x, \quad \frac{\partial v}{\partial y} = -2x \]
\[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 2x - 2x = 0 \Rightarrow \text{(Incompressible flow)} \]

b) Irrotational flows:
\[ \frac{\partial v}{\partial x} = -2y, \quad -\frac{\partial u}{\partial y} = -2y \]
\[ \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} = 0 \Rightarrow \text{The flow irrotational} \]

c) \[ p_{p_0} = \int_{p_0}^{p} v \cdot dv = \int_0^{1} (\nabla \cdot v) \, dv + \int_0^{2} (\nabla \cdot v) \, dv \]
\[ = \int_0^2 x \, dx + \int_0^2 y \, dy \]

d) No, it doesn't change 
(\psi \text{, flow not cross}) and because the stream function is constant

velocity potential
King Abdullah University
College of Engineering
Academic Accreditation Unit
Assessment Rubrics for Program Outcomes

Outcome (a): The artifact demonstrates the student’s ability to identify, formulate, and solve engineering problems

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Error in information is captured and distinguished from extraneous data</td>
<td>Consistently uses all exam information with little or no extraneous data</td>
<td>Ultimately identifies relevant information but may fail with extraneous data</td>
<td>Identifies some principles but seems to have difficulty in distinguishing what is needed.</td>
<td>Cannot identify and assemble relevant information.</td>
<td></td>
</tr>
<tr>
<td>2. The problem is approached and addressed in a logical and technically correct fashion</td>
<td>Student consistently and efficiently applies engineering principles. No conceptual or procedural errors occur.</td>
<td>Student can apply principles. Only rare and minor conceptual errors occur. Few procedural errors occur.</td>
<td>Student displays a general knowledge in all areas.</td>
<td>Student has significant technical problems in several of the listed areas.</td>
<td></td>
</tr>
<tr>
<td>3. The absence of necessary information is recognized and reasonable approximations are made</td>
<td>Consistently identifies and uses missing information using sound approximations. Attempts to recognize the limitations of the estimation.</td>
<td>Generally makes approximations of missing data. Recognizes that some error is introduced by approximating.</td>
<td>Will approximate, but may lack reasonable basis for approximating. May fail to appreciate limits imposed by approximations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The solution procedure is clearly marked and unambiguously defined</td>
<td>Presents step-by-step analysis which are logical and adequately explained.</td>
<td>Most of the steps are understandable, some steps lack detail or are confusing.</td>
<td>Some of the steps are understandable, most are confusing and lack detail.</td>
<td>Solution procedure is not organized, most steps are missing or are confusing.</td>
<td></td>
</tr>
<tr>
<td>5. The problem solution is usually correct and always reasonable</td>
<td>Has no more than one or two unanswerable issues. Answers, if any, are clear and unequivocal.</td>
<td>Attempts to evaluate answers but has difficulty in distinguishing what is needed.</td>
<td>Attempts to evaluate answers but has difficulty in distinguishing what is needed.</td>
<td>Makes little, if any, effort to interpret results. Numbers appear to have little meaning.</td>
<td></td>
</tr>
</tbody>
</table>
King AbdulAZIZ University
Faculty of Engineering
Aeronautical Engineering Department

AE-311: Incompressible Aerodynamics

Spring 2008
2nd Major EXAM

TIME ALLOWED 120 MIN.

Student’s Name: Abdulrahim Banoun
University I.D.#: 0250847

Rules:
- Answer all problems.
- The exam is closed book; no documents are allowed.
- Be clear and organized.
15% Problem #1:

a) Explain the physical meaning of “Kutta Condition” and show how it is enforced mathematically.

b) State Kelvin’s Theorem and how it is used to explain the existence of the bound vortex.

40% Problem #2:

a) The mean camber line of a thin airfoil may be approximated by three straight line segments as shown in the figure below. Find:

- The zero lift angle
- The lift coefficient for an angle of attack 4°

b) For a symmetric airfoil at an angle of attack 4°, Find:

- The zero lift angle
- The lift coefficient for an angle of attack 4°

20% Problem #3:

Consider an incompressible, steady-state boundary layer over flat plate of 1.2 m long, placed at zero angle-of-attack in the path of a uniform stream of air with velocity 4 m/s (viscosity is \( \mu = 1.789 \times 10^{-5} \text{ kg m}^{-1} \text{ sec} \), and the density is 1.225 kg m\(^{-3} \)).

(a) At a streamwise distance 0.6 m from the leading edge calculate the distances from the wall at which freestream velocity is half of the free-stream value.

(b) At the same streamwise location as above, calculate both the displacement and momentum thicknesses.

(c) Compute the skin friction drag coefficient.

25% Problem #4:

a) The shape of the pressure distribution is directly related to the airfoil performance. Explain how the following pressure distribution parameters affect airfoil performance:

1. Favorable pressure gradient
2. Minimum \( C_p \) value
3. Adverse pressure gradient
4. Trailing edge pressure

b) List the six steps to a Successful Airfoil Design.

c) How the trailing edge flap and the leading edge flap impact the lift coefficient and boundary layer behavior? Explain your answer.

d) How the load should be distributed along the airfoil chord to achieve low pitching moment?

e) What is the difference between laminar and turbulent boundary layers and how does that affect separation and drag.
Thin Airfoil Theory

\[ U \left( \frac{dy}{dx} - \alpha \right) = \frac{1}{2\pi} \int \frac{y}{x - x_1} \, dx \]

\[ x = \frac{c}{2} (1 - \cos \theta) \]

\[ \gamma = 2 U \left[ (\alpha - A_0) \frac{1 + \cos \theta}{\sin \theta} + \sum_{n=1} A_n \sin (n \theta) \right] \]

\[ A_0 = \frac{1}{\pi} \int \frac{dy}{\sin \theta} \, d\theta \]

\[ A_n = \frac{2}{\pi} \int \frac{dy}{\sin \theta} \cos (n \theta) \, d\theta \]

\[ C_L = 2 \pi \left( \alpha - A_0 + \frac{A_1}{2} \right) \]

\[ C_{M_{1,2}} = -\pi \left( \alpha - A_0 + \frac{A_1}{2} - \frac{A_2}{2} \right) \]

\[ C_W = -\pi \frac{A_1 - A_2}{4} \]

\[ \frac{x_{c,2}}{c} = \frac{1}{4} + \frac{\pi}{4C_L} (A_1 - A_2) \]
### Boundary Layer Theory

<table>
<thead>
<tr>
<th>Laminar Boundary Layer</th>
<th>Turbulent Boundary Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ \delta = 5.0 \frac{\sqrt{v'x}}{U} ]</td>
<td>[ \delta = 0.379 \frac{x}{(Re_x)^{1/5}} ]</td>
</tr>
<tr>
<td>[ \delta^* = 1.7208 \frac{\sqrt{v'x}}{U} ]</td>
<td>[ \delta^* = \frac{1}{8} ]</td>
</tr>
<tr>
<td>[ \theta = 0.664 \frac{\sqrt{v'x}}{U} ]</td>
<td>[ \theta = \frac{7}{8} ]</td>
</tr>
<tr>
<td>[ C_{D_x} = 1.328 / \sqrt{Re_L} ]</td>
<td>[ C_{D_x} = 0.074 / (Re_x)^{1/5} ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transition Boundary Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ C_{D_x} = \frac{0.074}{(Re_L)^{1/5}} - \frac{1700}{Re_L} ]</td>
</tr>
</tbody>
</table>
TRIGONOMETRY

Trigonometric functions are defined using a right triangle.

\[ \sin \theta = \frac{y}{r}, \cos \theta = \frac{x}{r} \]
\[ \tan \theta = \frac{y}{x}, \cot \theta = \frac{x}{y} \]
\[ \sec \theta = \frac{r}{x}, \csc \theta = \frac{r}{y} \]

Law of Sines
\[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \]

Law of Cosines
\[ a^2 = b^2 + c^2 - 2bc \cos A \]
\[ b^2 = a^2 + c^2 - 2ac \cos B \]
\[ c^2 = a^2 + b^2 - 2ab \cos C \]

Identities
\[ \cos \theta = 1 / \sin \theta \]
\[ \sec \theta = 1 / \cos \theta \]
\[ \tan \theta = \sin \theta / \cos \theta \]
\[ \csc \theta = 1 / \sin \theta \]
\[ \sin^2 \theta + \cos^2 \theta = 1 \]
\[ 1 + \tan^2 \theta = \sec^2 \theta \]
\[ 1 + \cot^2 \theta = \csc^2 \theta \]
\[ \sin (\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta \]
\[ \cos (\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta \]
\[ \sin 2\alpha = 2 \sin \alpha \cos \alpha \]
\[ \cos 2\alpha = \cos^2 \alpha - \sin^2 \alpha = 1 - 2 \sin^2 \alpha = 2 \cos^2 \alpha - 1 \]
\[ \tan 2\alpha = (2 \tan \alpha) / (1 - \tan^2 \alpha) \]
\[ \sin (\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta \]
\[ \cos (\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta \]
\[ \sin (\alpha - \beta) = \sin \alpha \cos \beta - \cos \alpha \sin \beta \]
\[ \cos (\alpha - \beta) = \cos \alpha \cos \beta + \sin \alpha \sin \beta \]
\[ \tan (\alpha - \beta) = (\tan \alpha - \tan \beta) / (1 + \tan \alpha \tan \beta) \]
\[ \cot (\alpha - \beta) = (\cot \alpha \cot \beta + 1) / (\cot \beta - \cot \alpha) \]
\[ \sin(\alpha/2) = \pm \sqrt{\frac{1 - \cos \alpha}{2}} \]
\[ \cos(\alpha/2) = \pm \sqrt{\frac{1 + \cos \alpha}{2}} \]
\[ \tan(\alpha/2) = \pm \sqrt{\frac{1 - \cos \alpha}{1 + \cos \alpha}} \]
\[ \cot(\alpha/2) = \pm \sqrt{\frac{1 + \cos \alpha}{1 - \cos \alpha}} \]

MATHEMATICS (continued)

\[ \sin \alpha \sin \beta = (1/2)(\cos(\alpha - \beta) - \cos(\alpha + \beta)) \]
\[ \cos \alpha \cos \beta = (1/2)(\cos(\alpha - \beta) + \cos(\alpha + \beta)) \]
\[ \sin \alpha \cos \beta = (1/2)(\sin(\alpha + \beta) + \sin(\alpha - \beta)) \]
\[ \sin \alpha \sin \beta = 2 \sin(\alpha/2) \cos(\alpha/2) \]
\[ \cos \alpha \cos \beta = 2 \cos(\alpha/2) \cos(\alpha/2) \]

COMPLEX NUMBERS

Definition
\[ i = \sqrt{-1} \]
\[ a + bi = (a + c) + i(b + d) \]
\[ (a + bi)(c - di) = (a - c) + i(b - d) \]
\[ (a + bi)(c + di) = (ac - bd) + i(ab + cd) \]
\[ a + ib = \frac{(a + ib)(c - id)}{c + id}(c + id) + (bc - ad) \]
\[ c + id \]
\[ (a + bi)(c - di) = 2a \]
\[ (a + ib)(a - ib) = a^2 + b^2 \]

Polar Coordinates
\[ x = r \cos \theta, y = r \sin \theta, \theta = \arctan(y/x) \]
\[ r = \sqrt{x^2 + y^2} \]
\[ \theta = \arctan(y/x) \]
\[ r = \sqrt{x^2 + y^2} \]
\[ \theta = \arctan(y/x) \]
\[ [r_1 \cos(\theta_1) + i \sin(\theta_1)][r_2 \cos(\theta_2) + i \sin(\theta_2)] = \frac{r_1 r_2 \cos(\theta_1 + \theta_2) + i \sin(\theta_1 + \theta_2)}{r_1 \cos(\theta_1) + i \sin(\theta_1)} \]
\[ r_1 \cos(\theta_1) + i \sin(\theta_1) \]
\[ r_2 \cos(\theta_2) + i \sin(\theta_2) \]
\[ \cos^n(\theta_1) + \sin^n(\theta_1) = \frac{2^n}{2^n} \cos(n \theta_1) + \sin(n \theta_1) \]
\[ \cos^n(\theta_1) + \sin^n(\theta_1) = \frac{2^n}{2^n} \cos(n \theta_1) + \sin(n \theta_1) \]

Euler's Identity
\[ e^{i\theta} = \cos \theta + i \sin \theta \]
\[ e^{-i\theta} = \cos -i \sin \theta \]
\[ \cos \theta = \frac{e^{i\theta} + e^{-i\theta}}{2}, \sin \theta = \frac{e^{i\theta} - e^{-i\theta}}{2i} \]

Roots
If \( k \) is any positive integer, any complex number (other than zero) has \( k \) distinct roots. The \( k \) roots of \( r \cos \theta + i \sin \theta \) can be found by substituting successively \( n = 0, 1, 2, \ldots, (k - 1) \) in the formula
\[ w = \sqrt{k} \left( \cos \left( \frac{\theta + 360\theta}{k} \right) + i \sin \left( \frac{\theta + 360\theta}{k} \right) \right) \]
DERIVATIVES AND INDEFINITE INTEGRALS

In these formulas, x, y, u, v, and w represent functions of x. Also, a, b, c, and k represent constants. All arguments of the trigonometric functions are in radians. A constant of integration should be added to the integrals. To avoid terminology difficulty, the following definitions are followed: arcsin \( u = \sin^{-1} u \), (sec \( u \))' = 1/sec \( u \).

1. \( \frac{du}{dx} = 0 \)
2. \( \frac{dv}{dx} = 1 \)
3. \( \frac{d(vw)}{dx} = v \frac{dw}{dx} + w \frac{dv}{dx} \)
4. \( \frac{d(u + v)}{dx} = \frac{du}{dx} + \frac{dv}{dx} \)
5. \( \frac{d(u/v)}{dx} = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2} \)
6. \( \frac{d}{dx} (u \cdot v) = u \frac{dv}{dx} + v \frac{du}{dx} \)
7. \( \frac{d}{dx} (\ln u) = \frac{1}{u} \frac{du}{dx} \)
8. \( \frac{d}{dx} (\ln a) = 0 \)
9. \( \frac{d}{dx} (\int f(x) \, dx) = f(x) \)
10. \( \frac{d}{dx} (\int_a^x f(t) \, dt) = f(x) \)
11. \( \frac{d}{dx} (\frac{x}{a}) = \frac{1}{a} \)
12. \( \frac{d}{dx} (\sin x) = \cos x \)
13. \( \frac{d}{dx} (\cos x) = -\sin x \)
14. \( \frac{d}{dx} (\tan x) = \sec^2 x \)
15. \( \frac{d}{dx} (\sec x) = \sec x \tan x \)
16. \( \frac{d}{dx} (\cot x) = -\csc^2 x \)
17. \( \frac{d}{dx} (\csc x) = -\csc x \cot x \)
18. \( \frac{d}{dx} (\sinh x) = \cosh x \)
19. \( \frac{d}{dx} (\cosh x) = \sinh x \)
20. \( \frac{d}{dx} (\tanh x) = \text{sech}^2 x \)
21. \( \frac{d}{dx} (\coth x) = -\text{csch}^2 x \)
22. \( \frac{d}{dx} (\ln \sqrt{u}) = \frac{1}{\sqrt{u}} \frac{du}{dx} \)
23. \( \frac{d}{dx} (\sqrt{u}) = \frac{1}{2 \sqrt{u}} \frac{du}{dx} \)
24. \( \frac{d}{dx} (\tan^{-1} x) = \frac{1}{1 + x^2} \frac{dx}{dx} \)
25. \( \frac{d}{dx} (\sec^{-1} x) = \frac{1}{x \sqrt{x^2 - 1}} \frac{dx}{dx} \)
26. \( \frac{d}{dx} (\csc^{-1} x) = \frac{1}{x \sqrt{x^2 - 1}} \frac{dx}{dx} \)
27. \( \frac{d}{dx} (\cot^{-1} x) = \frac{1}{x^2 + 1} \frac{dx}{dx} \)
28. \( \frac{d}{dx} (\sinh^{-1} x) = \frac{1}{\sqrt{x^2 + 1}} \frac{dx}{dx} \)
29. \( \frac{d}{dx} (\cosh^{-1} x) = \frac{1}{\sqrt{x^2 - 1}} \frac{dx}{dx} \)
30. \( \frac{d}{dx} (\tanh^{-1} x) = \frac{1}{1 - x^2} \frac{dx}{dx} \)
31. \( \frac{d}{dx} (\coth^{-1} x) = -\frac{1}{1 - x^2} \frac{dx}{dx} \)
32. \( \frac{d}{dx} (\text{sech}^{-1} x) = \frac{1}{x \sqrt{1 - x^2}} \frac{dx}{dx} \)
33. \( \frac{d}{dx} (\text{csch}^{-1} x) = -\frac{1}{x \sqrt{x^2 + 1}} \frac{dx}{dx} \)
34. \( \frac{d}{dx} (\text{arcsinh} x) = \frac{1}{\sqrt{x^2 + 1}} \frac{dx}{dx} \)
35. \( \frac{d}{dx} (\text{arccosh} x) = \frac{1}{\sqrt{x^2 - 1}} \frac{dx}{dx} \)
36. \( \frac{d}{dx} (\text{arctanh} x) = \frac{1}{1 - x^2} \frac{dx}{dx} \)
37. \( \frac{d}{dx} (\text{arccoth} x) = -\frac{1}{1 - x^2} \frac{dx}{dx} \)
38. \( \frac{d}{dx} (\text{arcsech} x) = \frac{1}{x \sqrt{1 - x^2}} \frac{dx}{dx} \)
39. \( \frac{d}{dx} (\text{arccsch} x) = -\frac{1}{x \sqrt{x^2 + 1}} \frac{dx}{dx} \)
40. \( \frac{d}{dx} (\text{arccosech} x) = \frac{1}{x \sqrt{1 - x^2}} \frac{dx}{dx} \)
For a given airfoil at a given angle of attack, the value of the circulation must be the unique value which ensures that the flow leaves the trailing edge smoothly. (The rear stagnation point is located at the trailing edge).

\[ L = \Phi \times \Gamma \]

b) Kelvin's Theorem.

The time rate of change of circulation around a closed curve consisting of the same fluid elements is equal to zero.
Part 2

\[ \frac{0.261 \pi}{2} \]
\[ \frac{0.3 \pi}{2} \]
\[ \frac{0.5065 \pi}{2} \]
\[ \times \]

Zero lift angle

\[ \alpha_L = A_0 - \frac{A_1}{2} \]

\[ \alpha_L = \frac{1}{\pi} \int_0^{\pi} \frac{d\psi}{r} \]

\[ C_L = 2 \pi (\alpha - A_0 + \frac{A_1}{2}) \]

\[ A_0 = \frac{1}{\pi} \int_0^{\pi} 0.261 \, d\psi \]

\[ A_0 = \frac{1}{\pi} \left[ 0 \right]_{0}^{0.5} + \frac{1}{\pi} \int_0^{0.5065} d\psi \]

\[ A_0 = \frac{1}{\pi} \left[ 0 \right]_{0}^{0.5} + \frac{1}{\pi} \left[ \omega \right]_0^{0.5} \]

\[ A_0 = \frac{1}{\pi} \left[ 0 \right]_{0}^{0.5} + \frac{1}{\pi} \left[ \omega \right]_0^{0.5} \times \]

Symmetric aileron

\[ C_L = 2 \pi \alpha \implies C_L = 2 \pi \text{(4)} \]

Zero lift angle

\[ C_L = 2 \pi \left( \alpha - A_0 + \frac{A_1}{2} \right) \]

\[ = 2 \pi \left( \frac{\pi}{2} - A_0 + \frac{A_1}{2} \right) \]

\[ = \times \]
\[ l = 1.2 \text{ m} \quad V = 4 \text{ m/s} \quad \Delta = 1.78 \times 10^{-3} \text{ kPa} \quad \beta = 1.275 \text{ kPa} \]

\[ \delta = \frac{V}{\beta} = \frac{1.78 \times 10^{-3}}{1.275} = 1.40 \times 10^{-5} \]

\[ \delta = 5.0 \sqrt{\frac{V}{U}} \Rightarrow \delta = 5.0 \sqrt{\frac{4}{6}} = 2.50 \times 10^{-3} \]

\[ \delta^* = 1.7208 \sqrt{\frac{Vx}{U}} \Rightarrow \delta^* = 1.7208 \sqrt{\frac{4 \times 10^{-3}}{6}} = 2.50 \times 10^{-3} \]

\[ \Theta = 0.66 \frac{Vx}{U} \Rightarrow \Theta = 0.958 \times 10^{-5} \]

\[ C_f = \frac{1.328}{\sqrt{Re}} \Rightarrow C_f = \frac{1.328}{\sqrt{3.286 \times 10^6}} = 2.316 \times 10^{-3} \]

\[ Re = \frac{pVl}{\mu} = \frac{3.286 \times 4 \times 1.2}{1.78 \times 10^{-3}} = 3.286 \times 10^6 \]
Successful aircraft design steps:

1. Acquire analysis tools: potential flow analysis, boundary layer analysis.
2. Validate the tools.
3. Specify design criteria.
4. Start with known aircraft shape.
5. Use an iterative process to improve the geometry/shape.
6. Use the new design in a 3-D analysis.

C. Trailing edge flap and leading edge flap (LEF).

- Let the separation be late at the leading edge and its short but the wing be more camber so that the impact of the lift coefficient.

Flap also let the wing shape be more camber so that effect with increasing of the $C_l$ by let the pressure increase at the trailing edge.
4. The fluid distributed along the airfoil chord consistently gives a positive pitching moment with low Re.

2. The laminar boundary gives lower K.E. at separation, gives lower skin friction and lower heating, and the flow here is uniform. The turbulent boundary gives high K.E. at separation, gives higher skin friction and high heating.
<table>
<thead>
<tr>
<th>Outcome (b): The artifact demonstrates the student's ability to identify, formulate, and solve engineering problems</th>
</tr>
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<tbody>
<tr>
<td><strong>Section</strong></td>
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<tr>
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King AbdulAZIZ University
Faculty of Engineering
Aeronautical Engineering Department

AE-311: Incompressible Aerodynamics

Spring 2008
3rd Major EXAM

TIME ALLOWED 90 MIN.

Student's Name: Abdullah Siadm
University I.D.#: 05181301

<table>
<thead>
<tr>
<th>Problem #</th>
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<th>2 (20%)</th>
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<th>Total</th>
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<td>30%</td>
<td>20%</td>
<td>20%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Rules:
• Answer ALL problems.
• The exam is closed book! so no documents are allowed.
• Be clear and organized.
**40% Problem #1:**

Consider an airplane that weighs 14700 N flying at 300 km/hr at an altitude where the density is 0.9093 kg/m³. The wing has an aspect ratio 6.2, a span of 10.266 m, and a thin airfoil section with zero-lift angle of -1.2°. If the load distribution is elliptic, calculate the following:

a) Induced drag coefficient.
b) Geometric angle of attack.
c) Effective angle of attack.
d) Downwash velocity at the root and the tip.
e) Value of circulation at the root.
f) Value of circulation at y=b/4.

**20% Problem #2:**

A general aviation aircraft has a wing area of 15.8 m² and a span of 9.75 m. Its maximum gross weight is 10900 N. The wing span-efficiency factor is 0.64. If the aircraft is cruising at 192 km/hr at standard sea-level (p=1.225 kg/m³) compute:

a) Lift coefficient
b) Induced drag coefficient.

**40% Problem #3:**

a) Consider a wing with an elliptic distribution and C\textsubscript{l} = 1.0. What is the section lift coefficient at the root of the wing?
b) What is the effective angle of attack? Explain why the angle of attack changes at the local airfoil section of the wing?
c) For a wing with a given aspect ratio, and lift coefficient, what can be done to keep the induced drag as small as possible?
d) Explain how the three wing planforms, shown below, could have the same local lift distribution while having different local lift coefficient.

![Diagram of wing planforms](image)
The Finite Wing Theory

Load Distribution:
\[ \Gamma = 2bV_e \sum_{n=1} A_n \sin(n \theta) \quad \text{for elliptic load distribution: } \Gamma = \Gamma_e \sin(\theta) \]

where \( y = \frac{b}{2} \cos \theta \)

Downwash:
\[ w = \frac{V_e}{\sin \theta} \sum_{n=1} \frac{A_n \sin(n \theta)}{n} \quad \text{for elliptic load distribution: } w = \frac{\Gamma_e}{2b} \frac{V_e}{\pi AR} \]

Induced angle of attack:
\[ \alpha_i = \frac{w}{V_e} \]

Wing Sectional Lift Coefficient:
\[ c_l = a_v (\alpha - \alpha_{i,v}) - \alpha_i \]

Wing Lift Coefficient:
\[ C_l = \pi AR A_1 \quad \text{for elliptic load distribution: } C_l = \frac{a_v (\alpha - \alpha_{i,v})}{1 + \frac{a}{\pi AR}} \]

Induced Drag Coefficient:
\[ C_d = \frac{C_i^2}{\pi AR} \quad \text{for elliptic load distribution: } e = 1 \]

\[ \delta = \left( \frac{A_2}{A_1} \right)^2 + 3 \left( \frac{A_3}{A_1} \right)^2 + 4 \left( \frac{A_4}{A_1} \right)^2 + \ldots \]

The Monoplane Equation:
\[ \mu (\alpha - \alpha_{i,v} + \alpha_{i,\infty}) = \sum_{n=1} A_n \sin(n \theta) \left[ 1 + \frac{n \mu}{\sin \theta} \right], \quad \mu = \frac{c a_v}{4b} \]
Problem

\( V = 300 \text{ km/h} \)

\( b = 10,266 \text{ m} \)

\( \alpha_{c} = 0.72 \text{ }^\circ \)

\( \alpha_{c0} = 0.12 \text{ }^\circ \)

\( \beta = 0.0294 \text{ rad} \)

\( R = 8.62 \text{ m} \)

\( S = 0.99093 \text{ m}^2 \)

\( \rho = 14280 \times 12 \times \text{ht} + (8.333)^2 \times 47 = 0.2739 \)

\( C_{L} = \frac{1}{\frac{1}{2} \rho V^2 S} \)

\( C_{L} = \frac{c_{L}(\alpha - \alpha_{CL_{max}})}{1 + \frac{c_{L}}{2 \pi C_{L_{max}}} \frac{2 \pi}{6.2 \times S}} \)

\( c_{L} = \frac{g_{L} g_{L}}{1 + \frac{g_{L}}{2 \pi C_{L_{max}}} \frac{2 \pi}{6.2 \times S}} \)

\( g_{L} = \frac{c_{L}}{2 \pi C_{L_{max}}} \frac{2 \pi}{6.2 \times S} \)

\( \alpha_{max} = \arctan \left( \frac{c_{L}}{2 \pi C_{L_{max}}} \frac{2 \pi}{6.2 \times S} \right) \)

\( \lambda = \frac{V_{L} c_{L} \sin \theta}{0.99093} \)

\( \pi = \frac{V_{L} c_{L} \sin \theta}{0.99093} \)

\( \pi = \frac{V_{L} c_{L} \sin \theta}{0.99093} \)

\( V_{L} = \frac{60}{2} \cos \theta \)

\( V_{L} = \frac{60}{2} \cos \theta \)

\( V_{L} = \frac{60}{2} \cos \theta \)

\( V_{L} = \frac{60}{2} \cos \theta \)
Problem 2

\[ S = 15.8 \quad D = 9.75 \quad L = 10900 \]

\[ S = 1.275 \quad \nu = 192 \text{ kN/m} \]

\[ C_L = \frac{(10900)^{1/2}}{(1.275)(.5335)^{1/2}} = 0.3960 \]

\[ A_R = \frac{V^2}{S} = \frac{(9.75)^2}{15.8} = 6.017 \]

\[ C_L = \frac{C_L}{A_R} \]

\[ A_1 = \frac{C_L}{A_R} = \frac{0.3960}{6.017} = 0.066 \]

\[ C_D = \frac{C_D}{A_R} \]

\[ \frac{(0.3960)^2}{6.017 \cdot 0.661} = 0.01296 \]
b) the effective angle of attack is the angle when downwash happen to airstream

\[ \text{effective angle of attack} \]

the angle of attack changes because the downwash office in tip and decrease to root

c) try to make elliptic load lift distribution

d) first wing is leading wing so the lift in root is high and low in tip because the downwash dump the lift

second wing is elliptic wing it help to keep constant CL in all wing

third wing look like the elliptic but have sweep angle
**Assessment Rubric for Program Outcomes**

**Outcome (a): The artifact demonstrates the student’s ability to identify, formulate, and solve engineering problems**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> Information is captured and distinguished from extraneous data</td>
<td>Consistently uses relevant information with little or no extraneous data.</td>
<td>Occasionally identifies relevant information but may start with extraneous data.</td>
<td>Identifies some principles but seems to have difficulty in distinguishing what is needed.</td>
<td>Cannot identify and assemble relevant information.</td>
</tr>
<tr>
<td><strong>2</strong> The problem is approached and modeled in a logical and technically correct fashion</td>
<td>Student consistently and efficiently applies engineering principles. No conceptual errors and few if any procedural errors exist. Student appears to be sound in all areas.</td>
<td>Student can apply principles. Only rare and minor conceptual errors exist. Few procedural errors. Student displays a working knowledge in all areas.</td>
<td>Student can apply principles but may need improvement in one or more areas. Some conceptual and procedural errors may be present.</td>
<td>Student has significant technical problems in several of the listed areas.</td>
</tr>
<tr>
<td><strong>3</strong> The absence of necessary information is recognized and reasonable approximations are made</td>
<td>Consistently identifies and estimates missing information using sound principles. Always recognizes the limitations of the approximations.</td>
<td>Generally realizes approximations of missing data. Recognizes that some error is introduced by approximating.</td>
<td>Will approximate, but may lack reasonable basis for approximating. May fail to appreciate limits imposed by approximations.</td>
<td>Becomes frustrated and gives up when errors are missing.</td>
</tr>
<tr>
<td><strong>4</strong> Other Solution Procedure</td>
<td>Premise may-decide steps which are logical and adequately detailed. Most of the steps are understandable, some steps lack detail or are confusing.</td>
<td>Some of the steps are understandable, most are confusing and lack detail.</td>
<td>Some of the steps are understandable, most are confusing and lack detail.</td>
<td>Some steps are missing.</td>
</tr>
<tr>
<td><strong>5</strong> The problem solution is usually correct and always reasonable.</td>
<td>The no more than one or two unrecognized implicit assumptions. If any, it is minor and obvious.</td>
<td>Attempt to evaluate answers but has difficulty recognizing that number have meaning but cannot fully state or justify.</td>
<td>Attempts to evaluate answers but has difficulty recognizing that number have meaning but cannot fully state or justify.</td>
<td>Format is not clear, and no attempt is made to interpret results. Numbers appear to have little meaning.</td>
</tr>
</tbody>
</table>
King AbdulAZIZ University
Faculty of Engineering
Aeronautical Engineering Department

AE-311: Incompressible Aerodynamics

Spring 2008
Final EXAM – Part One

TIME ALLOWED 90 MIN.

Student's Name: Rayyan Salaimin Akramuddin
University I.D.#: 0950289

<table>
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<td>40%</td>
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</tbody>
</table>

Rules:
- Answer All Questions.
- The exam is closed book! So no documents are allowed.
- Be clear and organized.
30% Problem #1:

The stream function of a low-speed two-dimensional flow is given by:
\[ \psi = 2x + 5y - 7\tan^{-1}\left(\frac{y}{x}\right) \]

\(\checkmark\) a) Show that the stream function describes an incompressible irrotational flow.
\(\times\) b) Find the volume flow between the two points (1,1) and (2,2).
\(\times\) c) If the pressure at the origin is 6bars and the density is 1.2kg/m^3, find the pressure at the point (1.2)
\(\times\) d) Find the expression for the velocity potential.

30% Problem #2:

Consider a source placed above a flat plate in a uniform flow as shown in figure X.

\(\checkmark\) a) Name and sketch the elementary flows combination that will simulate this flow.
\(\checkmark\) b) Find the pressure coefficient \(c_p(x)\) on the plate
\(\times\) c) Sketch the streamlines for this flow.
**10% Problem #3:**

Consider two sources of strength (+$\Lambda$) and a sink of strength (-2$\Lambda$) in a uniform positioned as shown in figure.

- Find $\beta$ such that the origin ($x=0, y=0$) is a stagnation point.

![Diagram showing sources and sink]

**30% Problem #4:**

- a) Explain the difference between Eulerian and Lagrangian approaches in deriving the governing equations.
- b) State the assumptions for incompressible potential flow.
- c) Define vorticity and circulation.
- d) What is the difference between rotational flow and irrotational flow?
- e) State Kutta-Joukowski Theorem.
- f) State the general approach for the solution of incompressible potential flow.
Elementary flows

Uniform Flow:
\[ \psi = uy - vx \]
\[ \phi = ux + vy \]

Source-sink flow:
\[ \psi = \pm \frac{\Lambda}{2\pi} \theta \]
\[ \phi = \pm \frac{\Lambda}{2\pi} \ln \left( \frac{r}{r_0} \right) \]

Vortex flow:
\[ \psi = \frac{\Gamma}{2\pi} \ln \left( \frac{r}{r_0} \right) \]
\[ \phi = \pm \frac{\Gamma}{2\pi} \theta \]

Doublet flow:
\[ \psi = -\frac{\kappa \sin \theta}{2\pi r} \]
\[ \phi = \frac{\kappa \cos \theta}{2\pi r} \]

Relation between velocity and \( \psi \) & \( \phi \):
\[ u = -\frac{\partial \psi}{\partial y}, \quad v = \frac{\partial \psi}{\partial x}, \quad u = \frac{\partial \phi}{\partial y}, \quad v = \frac{\partial \phi}{\partial x}, \quad u = \frac{1}{r} \frac{\partial \psi}{\partial \theta}, \quad u = \frac{\partial \phi}{\partial \theta} \]
\[ u = \frac{\partial \psi}{\partial r} \]
\[ u = \frac{\partial \phi}{\partial r} \]
\[ u = \frac{1}{r} \frac{\partial \psi}{\partial \theta} \]

Continuity Equation:
\[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \]
\[ \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{1}{r} \frac{\partial u}{\partial \theta} = 0 \]
\[ \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0 \]
\[ \frac{\partial^2 \phi}{\partial r^2} + \frac{\partial \phi}{\partial r} + \frac{1}{r} \frac{\partial \phi}{\partial \theta} = 0 \]

Vorticity Equation:
\[ \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = \xi \]
\[ \frac{\partial v}{\partial r} - \frac{u}{r} \frac{\partial u}{\partial \theta} - \frac{1}{r} \frac{\partial u}{\partial r} = \xi \]
\[ \frac{\partial \psi}{\partial x} + \frac{\partial \psi}{\partial y} = \xi \]
\[ \frac{\partial^2 \psi}{\partial r^2} + \frac{\partial \psi}{\partial r} + \frac{\partial^2 \psi}{\partial \theta^2} = \xi \]
DERIVATIVES AND INDEFINITE INTEGRALS

In these formulas, u, v, and w represent functions of x. Also, a, c, and b represent constants. All arguments of the trigonometric functions are in radians. A constant of integration should be added to the integrals. To avoid terminology difficulty, the following definitions are followed: arcsin u = \sin^{-1} u, (\sin x)^n = \frac{1}{n!} \sin n u.

1. \frac{dv}{dx} = 0
2. \frac{dv}{dx} = 1
3. \frac{dv}{dx} = c \frac{du}{dx}
4. \frac{d}{dx} (u + v) = \frac{du}{dx} + \frac{dv}{dx}
5. \frac{d}{dx} (u - v) = \frac{du}{dx} - \frac{dv}{dx}
6. \frac{d}{dx} (uv) = u \frac{dv}{dx} + v \frac{du}{dx}
7. \frac{d}{dx} \left( \frac{u}{v} \right) = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}
8. \frac{d}{dx} (u^v) = v u^{v-1} \frac{du}{dx}
9. \frac{d}{dx} (f(u)v(u)) = f'(u) \frac{du}{dx} v(u) + f(u) \frac{dv}{dx} u(u)
10. \frac{d}{dx} (\frac{u}{v}) = \frac{\frac{dv}{dx} u - \frac{du}{dx} v}{v^2}
11. \frac{d}{dx} (\ln x) = \frac{1}{x}
12. \frac{d}{dx} (e^{ax}) = ae^{ax}
13. \frac{d}{dx} (\log_a x) = \frac{1}{x \ln a}
14. \frac{d}{dx} \left( e^{ax} \right) = ae^{ax}
15. \frac{d}{dx} (u^a) = au^{a-1} \frac{du}{dx} + (\ln u) u^a \frac{du}{dx}
16. \frac{d}{dx} (\sin u) = \cos u \frac{du}{dx}
17. \frac{d}{dx} (\cos u) = -\sin u \frac{du}{dx}
18. \frac{d}{dx} (\tan u) = \sec^2 u \frac{du}{dx}
19. \frac{d}{dx} (\cot u) = -\csc^2 u \frac{du}{dx}
20. \frac{d}{dx} (\sec u) = \sec u \tan u \frac{du}{dx}
21. \frac{d}{dx} (\csc u) = -\csc u \cot u \frac{du}{dx}
22. \frac{d}{dx} \left( \sin^{-1} u \right) = \frac{1}{\sqrt{1 - u^2}} \frac{du}{dx} (-\pi/2 \leq \sin^{-1} u \leq \pi/2)
23. \frac{d}{dx} \left( \cos^{-1} u \right) = \frac{1}{\sqrt{1 - u^2}} \frac{du}{dx} (0 \leq \cos^{-1} u \leq \pi)
24. \frac{d}{dx} \left( \tan^{-1} u \right) = \frac{1}{1 + u^2} \frac{du}{dx} (-\pi/2 < \tan^{-1} u < \pi/2)
25. \frac{d}{dx} \left( \cot^{-1} u \right) = \frac{1}{1 + u^2} \frac{du}{dx} (0 < \cot^{-1} u < \pi)
26. \frac{d}{dx} \left( \sec^{-1} u \right) = \frac{1}{u \sqrt{u^2 - 1}} \frac{du}{dx} (|u| \geq 1) \quad (0 \leq \sec^{-1} u \leq \pi/2)
27. \frac{d}{dx} \left( \csc^{-1} u \right) = \frac{1}{u \sqrt{u^2 - 1}} \frac{du}{dx} (|u| \geq 1) \quad (0 < \csc^{-1} u \leq \pi/2)
TRIGONOMETRY
Trigonometric functions are defined using a right triangle.
\[
\sin \theta = \frac{y}{r}, \quad \cos \theta = \frac{x}{r}, \quad \tan \theta = \frac{y}{x}, \quad \cot \theta = \frac{x}{y}, \quad \sec \theta = \frac{r}{x}, \quad \csc \theta = \frac{r}{y}.
\]

Law of Sines
\[
\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}.
\]

Law of Cosines
\[
a^2 = b^2 + c^2 - 2bc \cos A, \\
b^2 = a^2 + c^2 - 2ac \cos B, \\
c^2 = a^2 + b^2 - 2ab \cos C.
\]

Identities
\[
\cos^2 \theta + \sin^2 \theta = 1, \\
\tan \theta = \frac{\sin \theta}{\cos \theta}, \\
\cot \theta = \frac{\cos \theta}{\sin \theta}, \\
\sec \theta = \frac{1}{\cos \theta}, \\
\csc \theta = \frac{1}{\sin \theta}.
\]

Complex Numbers
Definition: \(i = \sqrt{-1}\)
\[
(a + bi) + (c + di) = (a + c) + i(b + d), \\
(a + bi) - (c + di) = (a - c) + i(b - d), \\
(a + bi) \cdot (c + di) = (ac - bd) + i(ad + bc).
\]

Polar Coordinates
\[
x = r \cos \theta, \quad y = r \sin \theta, \quad \theta = \arctan \left( \frac{y}{x} \right),
\]
\[
r = \sqrt{x^2 + y^2}.
\]

Euler's Identity
\[
e^{i \theta} = \cos \theta + i \sin \theta,
\]
\[
e^{-i \theta} = \cos \theta - i \sin \theta.
\]

Roots
If \(k\) is any positive integer, any complex number (other than zero) has \(k\) distinct roots. The \(k\) roots of \(r (\cos \theta + i \sin \theta)\) can be found by substituting successively \(n = 0, 1, 2, \ldots, (k - 1)\) in the formula
\[
w = \sqrt[k]{r} \left( \cos \left( \frac{\theta + 2\pi n}{k} \right) + i \sin \left( \frac{\theta + 2\pi n}{k} \right) \right).
\]

Matrices
A matrix is an ordered rectangular array of numbers with \(m\) rows and \(n\) columns. The element \(a_{ij}\) refers to row \(i\) and column \(j\).
Problem 1

$\psi = 2x + 5y - 7 \tan^{-1}\left(\frac{y}{x}\right)$

a)

\[
u = \frac{\partial \psi}{\partial y} = 5 - 7\cdot \frac{y}{1 + \frac{y^2}{x^2}} \cdot \frac{1}{x^2}
\]

\[
u = - \frac{\partial \psi}{\partial x} = 2 + 7\cdot \frac{1}{1 + \frac{y^2}{x^2}} \cdot \frac{1}{x}
\]

* For irrotational: $\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 1 - 1 = 0$ (irrotational), but how?

* For Incompressible: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$ (Incompressible)

\[
\frac{\partial u}{\partial x} = 0 \quad (1)
\]

\[
\frac{\partial v}{\partial y} = 0 \quad (2)
\]

b) Volume flow through two point (1, 1) & (2, 2)

\[
\mathbf{V} = \int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds + \int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds
\]

where $\int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds = \int_{1}^{2} \nabla \cdot \mathbf{v} \, ds$ (by Using theorem)

Volume flow along two point (1, 1) & (2, 2)

\[
= \int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds + \int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds
\]

where $\int_{1}^{2} \nabla \cdot \mathbf{v} \cdot \mathbf{n} \, ds = \int_{1}^{2} \nabla \cdot \mathbf{v} \, ds$ (by Divergence theorem)
c) \[ P_0 = 6 \times 10^5 \text{ N/m}^2 \]
\[ p = 1.2 \text{ kg/m}^3 \]

The pressure is surface force:

\[ -\int P \cdot ds = -\int P \cdot n \cdot ds \Rightarrow -\int P \cdot ds \cdot ds \]

\[ -\int P \cdot ds \cdot n = -\int \nabla P \cdot dv \text{ (by Using Theorem)} \]

\[ \nabla P = \frac{\partial P}{\partial x} + \frac{\partial P}{\partial y} \]

\[ \frac{dy}{dv} = \frac{-\frac{u}{v}}{v} \] (slope for velocity potential)

\[ \frac{dy}{dx} = -\frac{\frac{1}{4} \frac{y}{x^2} + \frac{1}{4} \frac{y}{x^2}}{4 + \frac{1}{4} \frac{y}{x^2} + \frac{1}{4} \frac{y}{x^2}} = -\frac{2 \frac{y}{x^2}}{4 + \frac{1}{4} \frac{y}{x^2} + \frac{1}{4} \frac{y}{x^2}} = -\frac{2 \frac{y}{x^2}}{5 \frac{y}{x^2}} = \frac{dy}{dx} \]

Then will Integral \[ \int \frac{dy}{dx} \]

X
Problem 2

(a) Flow combinations:

Uniform flow + Source \((\text{Ramke})\)

\[
\psi = \psi_{\text{uniform}} + \psi_{\text{source}}
\]

\[
\varepsilon \cos \theta + \frac{\lambda}{2\pi} (\theta_1 + \theta_2)
\]

where \(y = r \sin \theta\)

\[
= V_{\infty} y + \frac{\lambda}{2\pi} \left[ \tan^{-1} \left( \frac{y-H}{x} \right) + \tan^{-1} \left( \frac{y+H}{x} \right) \right]
\]

We will denote diff. streamline \(E_i\) as:

\[
u = \frac{\partial \psi}{\partial y} = V_{\infty} + \frac{\lambda}{2\pi} \left[ \frac{1}{1 + \left( \frac{y-H}{R} \right)^2} + \frac{1}{1 + \left( \frac{y+H}{x} \right)^2} \right]
\]

\[
\nu = \frac{\partial \psi}{\partial x} = \frac{\lambda}{2\pi} \left[ \tan^{-1} \left( \frac{y-H}{x} \right) + \frac{1}{1 + \left( \frac{y-H}{x} \right)^2} + \frac{1}{1 + \left( \frac{y+H}{x} \right)^2} \right]
\]

At stagnation point:

\[
\psi = 0 \quad \Rightarrow \quad V = 0
\]

\[
\frac{C_p}{1 - \frac{u^2}{V_{\infty}^2}} = 0
\]
Problem 8.3
\[ \psi = \psi_{\text{uniform}} + \psi_{\text{source}} \]
\[ + \psi_{\text{sink}} \]
\[ x = b \]
\[ x = \beta \]
where \( x = r \cos \Theta \), \( y = r \sin \Theta \)

Problem 8.4

(a) Eulerian:

Lagrangian: We solved the conservation of mass and momentum

(b) assumptions flow:

- For steady flow, the time derivative is zero:
  \[ \nabla \cdot (\rho \vec{v}) = 0 \]

- For incompressible flow, \( \rho \) is constant:
  \[ \nabla \cdot \vec{v} = 0 \]
King AbdulAZIZ University
Faculty of Engineering
Aeronautical Engineering Department

AE-311: Incompressible Aerodynamics

Spring 2008
Final EXAM - Part Two

TIME ALLOWED 120 MIN.

Student's Name: Rayyan Selaimen Akramuddin
University I.D.#: 0450289

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Rules:
- Answer All Questions.
- The exam is closed book! so no documents are allowed.
- Be clear and organized.
30% Problem #1:
Consider a symmetric airfoil with a flap, as shown (at zero thickness) in the figure. Find: \( C_L \), \( C_{M_{LZ}} \), and \( X_{C_F} \) for \( \alpha \) of 10° if the flap length is 20% of chord and the flap deflection \( \delta \) is 15° downward.

\[ \alpha \]

\[ \delta \]

\[ \text{Flap} \]

20% Problem #2:
A wing has a total span of 10m, root chord 3m, and a taper ratio of 0.6. The wing section is a cambered airfoil with zero lift angle of -2°. The wing is twisted such that the effective angle of attack changes linearly from 10° at the root to 4° at the tip. The aircraft is flying at 60m/sec at sea level (density is 1.225 kg/m³). Find:
1. The aspect ratio.
2. The wing area.
3. The sectional lift force (\( l \)) at the wing semi-span.

10% Problem #3:
An airplane weighing 35kN is cruising at 300 km/hr at standard sea-level (\( \rho = 1.225 \text{ kg/m}^3 \)). The airplane has a wing with an area of 20m² and a span of 15m. The airfoil section used in the wing is symmetric and has a lift slope of 2\( \pi \) and the geometrical angle of attack is 4°. If the wing has a constant downwash, compute:

✓ The induced drag coefficient
✓ The sectional Lift coefficient
10% Problem #4:

a) Explain the process of Aerodynamic Heating?

b) What is the difference between skin-friction drag and pressure drag (i.e., what is the cause of each one of them?)

c) What are the effects of Laminar and Turbulent flow on: Separation, Shear Stress, and Heat Transfer?

d) How does leading-edge flap and trailing-edge flap affect the behavior of the boundary layer?

15% Problem #5:

a) Which is more desirable at the trailing edge: high pressure or low pressure and why?

b) What is the difference between single-point design and multi-point point design? Give an example.

c) What do we need to maintain in order to achieve laminar flow over an airfoil?

d) How the load should be distributed along the airfoil chord to achieve low pitching moment? and why?

15% Problem #6:

The Lockheed U2 reconnaissance airplane flies at subsonic speeds at an altitude of 70,000 ft, where the density of air is about one-twentieth the sea-level density of air. Its wings have an aspect ratio of 14.3.

\[ \text{L} = \frac{1}{2} \rho V^2 S C_L \]

a) Using the equation for lift \( L = \frac{1}{2} \rho V^2 S C_L \), explain why the U2 is designed to cruise near stall conditions.

b) Given that the induced drag coefficient is given by \( C_D = \frac{C_{D_{ind}}}{\pi AR \rho} \), discuss why the U2 requires very high aspect ratio wings.

c) Why the plane was required to fly at altitude?
THE GENERAL THIN AIRFOIL THEORY

\[ U \left( \frac{dy}{dx} - \sigma \right) = \frac{1}{2\pi} \int \frac{\gamma}{x - x_i} dx \]

\[ x = \frac{c}{2} (1 - \cos \theta) \]

\[ \gamma = 2U \left( \alpha - \Lambda_a \right) \frac{1 + \cos \theta}{\sin \theta} + \sum \Lambda_n \sin (n\theta) \]

\[ A_b = \frac{1}{\pi} \int \frac{dy}{dx} d\theta \]

\[ A_c = \frac{2}{\pi} \int \frac{dy}{dx} \cos (n\theta) d\theta \]

\[ C_L = 2\pi \left( \alpha - \Lambda_a - \frac{\Lambda_b}{2} \right) \]

\[ C_{L,\infty} = -\frac{\pi}{2} \left( \alpha - \Lambda_a + \Lambda_c - \frac{\Lambda_2}{2} \right) \]

\[ C_{\infty} = -\frac{\pi}{4} (\Lambda_1 - \Lambda_2) \]

\[ \frac{x_c}{c} = \frac{1}{4} + \frac{\pi}{4C_L} (\Lambda_1 - \Lambda_2) \]

**Useful Relations and Integrals:**

\[ \cos 2\theta = 2\cos^2 \theta - 1 \]

\[ \int \cos \theta = \sin \theta \]

\[ \int \cos^2 \theta = \frac{\theta}{2} + \frac{1}{2} \sin \theta \cos \theta \]

\[ \int \sin^2 \theta = \frac{\theta}{2} - \frac{1}{2} \sin \theta \cos \theta \]
The Finite Wing Theory

Load Distribution:

\[ \Gamma = 2b \sqrt{\pi} \sum_{n=1}^{\infty} A_n \sin(n\theta) \quad , \text{for elliptic load distribution: } \Gamma = \Gamma_i \sin(\theta) \]

\[ w = \frac{V_p}{\sin \theta} \sum_{n=1}^{\infty} nA_n \sin(n\theta) \quad , \text{for elliptic load distribution: } w = \frac{\Gamma_i}{2b} \frac{VC}{\pi AR} \]

Downwash:

Induced angle of attack:

\[ \alpha_i = \frac{w}{V_p} \]

Wing Sectional Lift coefficient:

\[ cl = a_0 (\alpha - \alpha_{\mu=0} - \alpha_i) = a_0 (\alpha_{\mu} - \alpha_{\mu=0}) \]

Wing Lift coefficient:

\[ C_L = \pi AR A_i \quad , \text{for elliptic load distribution: } C_L = \frac{a_0 (\alpha - \alpha_{\mu=0})}{1 + \frac{a_0}{\pi AR}} \]

Induced Drag Coefficient:

\[ C_D = \frac{C_L^2}{\pi AR} \cdot e = \frac{1}{1 + \delta} \quad , \text{for elliptic load distribution: } e = 1 \]

\[ \delta = 2 \left( \frac{A_2}{A_1} \right)^2 + 3 \left( \frac{A_3}{A_1} \right)^2 + 4 \left( \frac{A_4}{A_1} \right)^2 + \ldots \]

The Monoplane Equation:

\[ \mu(\alpha - \alpha_{\mu=0} - \alpha_{\mu=0}) = \sum_{n=1}^{\infty} A_n \sin(n\theta) \left[ 1 + \frac{n \mu}{\sin \theta} \right] \quad , \quad \mu = \frac{ca_0}{4b} \]
TRIGONOMETRY

Trigonometric functions are defined using a right triangle.

\[ \sin \theta = \frac{y}{r}, \quad \cos \theta = \frac{x}{r}, \quad \tan \theta = \frac{y}{x}, \quad \cot \theta = \frac{x}{y}, \quad \sec \theta = \frac{r}{x}, \quad \csc \theta = \frac{r}{y} \]

Law of Sines: \[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \]

Law of Cosines: \[ a^2 = b^2 + c^2 - 2bc \cos A \]
[\[ b^2 = a^2 + c^2 - 2ac \cos B \]
[\[ c^2 = a^2 + b^2 - 2ab \cos C \]

Identities

\[ e^\theta = \cos \theta + i \sin \theta \]
\[ e^{-\theta} = \cos \theta - i \sin \theta \]
\[ e^{i\theta} = \cos \theta + i \sin \theta \]
\[ e^{-i\theta} = \cos \theta - i \sin \theta \]

\[ \sin \alpha \sin \beta = \frac{1}{2} [\cos (\alpha - \beta) - \cos (\alpha + \beta)] \]
\[ \cos \alpha \cos \beta = \frac{1}{2} [\cos (\alpha - \beta) + \cos (\alpha + \beta)] \]
\[ \sin \alpha \cos \beta = \frac{1}{2} [\sin (\alpha + \beta) + \sin (\alpha - \beta)] \]
\[ \sin \alpha + \sin \beta = 2 \sin (\frac{1}{2}(\alpha + \beta)) \cos (\frac{1}{2}(\alpha - \beta)) \]
\[ \sin \alpha - \sin \beta = 2 \cos (\frac{1}{2}(\alpha + \beta)) \sin (\frac{1}{2}(\alpha - \beta)) \]
\[ \cos \alpha + \cos \beta = 2 \cos (\frac{1}{2}(\alpha + \beta)) \cos (\frac{1}{2}(\alpha - \beta)) \]
\[ \cos \alpha - \cos \beta = -2 \sin (\frac{1}{2}(\alpha + \beta)) \sin (\frac{1}{2}(\alpha - \beta)) \]

COMPLEX NUMBERS

Definition: \[ i = \sqrt{-1} \]
\[ (a + b) + (c + di) = (a + c) + i(b + d) \]
\[ (a - b) - (c - di) = (a - c) - i(b - d) \]
\[ (a + bi)(c + di) = (ac - bd) + i(bc + ad) \]
\[ c + id \]
\[ (a + b) - (c + di) = 2a \]
\[ (a + b) - (c - di) = 2b \]
\[ (a + bi)(c - di) = ac + bd \]

Polar Coordinates

\[ x = r \cos \theta, \quad y = r \sin \theta \]
\[ r = \sqrt{x^2 + y^2} \]
\[ x + iy = r (\cos \theta + i \sin \theta) = re^i\theta \]
\[ r e^{i\theta} = r e^{i\theta} \]
\[ e^{i\theta} = \cos \theta + i \sin \theta \]
\[ e^{-i\theta} = \cos \theta - i \sin \theta \]

Euler's Identity

\[ e^\pi = -1 \]

Roots

If \( k \) is any positive integer, any complex number (other than zero) has \( k \) distinct roots. The \( k \) roots of \( r \) \( \cos \theta + i \sin \theta \) can be found by substituting successively \( n = 0, 1, 2, \ldots, (k - 1) \) in the formula:

\[ e^{2\pi i n / k} \]

MATRICES

A matrix is an ordered rectangular array of numbers with \( m \) rows and \( n \) columns. The element \( a_{ij} \) refers to row \( i \) and column \( j \).
DERIVATIVES AND INDEFINITE INTEGRALS

In these formulas, u, v, and w represent functions of x. Also, a, b, c, and n represent constants. All arguments of the trigonometric functions are in radians. A constant of integration should be added to the integrals. To avoid terminology difficulty, the following definitions are followed: arcsec u = \arccos \frac{1}{u}, (\sin u)^{-1} = 1/\sin u.

1. \frac{d}{dx} \arcsin v = \frac{1}{\sqrt{1 - v^2}} \frac{dv}{dx}
2. \frac{d}{dx} \arccos u = -\frac{1}{\sqrt{1 - u^2}} \frac{du}{dx}
3. \frac{d}{dx} \arctan u = \frac{1}{1 + u^2} \frac{du}{dx}
4. \frac{d}{dx} \arccot u = -\frac{1}{1 + u^2} \frac{du}{dx}
5. \frac{d}{dx} \arcsec u = \frac{1}{u \sqrt{u^2 - 1}} \frac{du}{dx}
6. \frac{d}{dx} \arccsc u = \frac{1}{u \sqrt{u^2 + 1}} \frac{du}{dx}

7. \int \frac{du}{\sqrt{u^2 - a^2}} = \ln |u + \sqrt{u^2 - a^2}| + C
8. \int \frac{du}{\sqrt{b^2 - a^2}} = \frac{u}{b} \sqrt{b^2 - u^2} + C
9. \int \frac{du}{u \sqrt{a^2 - u^2}} = -\frac{1}{a} \ln |u + \sqrt{a^2 - u^2}| + C
10. \int \frac{du}{u \sqrt{a^2 + u^2}} = \ln |u + \sqrt{a^2 + u^2}| + C
11. \int \frac{du}{u \sqrt{a^2 - u^2}} = \ln |u - \sqrt{a^2 - u^2}| + C
12. \int \frac{du}{u \sqrt{a^2 + u^2}} = \ln |u - \sqrt{a^2 + u^2}| + C

13. \int \frac{du}{\sqrt{u^2 + a^2}} = \ln |u + \sqrt{u^2 + a^2}| + C
14. \int \frac{du}{u \sqrt{u^2 + a^2}} = \ln |u - \sqrt{u^2 + a^2}| + C
15. \int \frac{du}{u \sqrt{u^2 - a^2}} = \ln |u + \sqrt{u^2 - a^2}| + C
16. \int \frac{du}{u \sqrt{a^2 - u^2}} = \ln |u - \sqrt{a^2 - u^2}| + C

17. \int \frac{dv}{\sqrt{v^2 + a^2}} = \ln |v + \sqrt{v^2 + a^2}| + C
18. \int \frac{dv}{v \sqrt{v^2 + a^2}} = \ln \left| v - \sqrt{v^2 + a^2} \right| + C
19. \int \frac{dv}{v \sqrt{a^2 - v^2}} = \ln \left| v + \sqrt{a^2 - v^2} \right| + C
20. \int \frac{dv}{v \sqrt{a^2 + v^2}} = \ln \left| v - \sqrt{a^2 + v^2} \right| + C

21. \int \frac{u \, dv}{v^2 - a^2} = \frac{1}{2a} \ln \left| \frac{u + a}{u - a} \right| + C
22. \int \frac{u \, dv}{v^2 + a^2} = \frac{1}{a} \tan^{-1} \left( \frac{u}{a} \right) + C
23. \int \frac{u \, dv}{v^2 - a^2} = \frac{1}{a} \ln \left| \frac{u + a}{u - a} \right| + C
24. \int \frac{u \, dv}{v^2 + a^2} = \frac{1}{a} \tan^{-1} \left( \frac{u}{a} \right) + C

25. \int \frac{u \, dv}{v^2 - a^2} = \frac{1}{2a} \ln \left| \frac{u + a}{u - a} \right| + C
26. \int \frac{u \, dv}{v^2 + a^2} = \frac{1}{a} \tan^{-1} \left( \frac{u}{a} \right) + C
27. \int \frac{u \, dv}{v^2 - a^2} = \frac{1}{2a} \ln \left| \frac{u + a}{u - a} \right| + C
28. \int \frac{u \, dv}{v^2 + a^2} = \frac{1}{a} \tan^{-1} \left( \frac{u}{a} \right) + C
Problem 1

\[ x = \frac{\alpha}{0.2e} \]

\[ \alpha = 10^\circ, \theta = 0.17 \text{ rad} \]

\[ \frac{dy}{dx} = \begin{cases} 0 & 0 \leq \theta \leq 0.8 \\ -\frac{\tan \theta}{\theta} & 0.8 \leq \theta \leq 3.1 \\ -0.2 & 3.1 \leq \theta \end{cases} \]

\[ x = 0.2e \times \frac{x}{45^\circ} = \frac{\theta}{3.1} (1 - \cos \theta) \Rightarrow 0.2 = \frac{\theta}{3.1} (1 - \cos \theta) \times 2 \]

\[ \Rightarrow 0.4 = 1 - \cos \theta \Rightarrow \cos \theta = 1 - 0.4 = 0.6 \]

\[ \theta = \cos^{-1} 0.6 = 53.1^\circ \approx 0.92 \text{ rad} \]

\[ C_0 = \frac{2\pi}{2} \left[ \frac{1}{\theta} \int_0^{\theta} \frac{dy}{dx} \cos \theta \, d\theta + \frac{1}{n} \int_0^{\theta} \frac{dy}{dx} \sin \theta \, d\theta \right] \]

\[ A_0 = \frac{2}{n} \left( \tan 15^\circ \times \frac{\pi}{180} \times \frac{\sin \theta}{3.1} \right) + \frac{2}{n} \tan 15^\circ \times \frac{\pi}{180} \times \frac{\sin \theta}{2} \]

\[ A_1 = \frac{2}{n} x \]

\[ C_M \varepsilon = -\frac{\pi}{2} \left( x - A_0 + A_1 - \frac{A_1^2}{2} \right) \]

\[ \frac{x_{cp}}{e} = \frac{1}{4} \]
Problem 3.2

\[ b = 10 \, m, \quad C_{\text{ant}} = 3 \, m, \quad \lambda = 0.6, \quad \alpha = -7 \times \frac{m}{\text{s}^2} = 0.02 \, \text{rad} \]

\[ U = 60 \, m/s, \quad \rho = 1.225 \, \text{kg/m}^3, \quad \alpha = 10^\circ, \quad \alpha_{\text{tip}} = 4^\circ \times \frac{180}{\pi} = 0.07 \, \text{rad} \]

1. \[ AR = \frac{b}{s} \]

2. \[ \lambda = \frac{C_{\text{ant}}}{C_{\text{tip}}} \]

3. \[ 0.6 = \frac{3}{C_{\text{tip}}} \implies C_{\text{tip}} = 5 \, m \]

4. \[ S = b \cdot C = 10 \cdot \frac{2}{C} = 0 \quad \text{m}^2 \implies \frac{10}{2} \implies AR = \frac{b}{C} \]

5. \[ C = C_{\text{ant}} \left( C_{\text{tip}} - \cos \theta \right) - 1 \]

6. \[ \theta = \frac{\pi}{6} \, \text{radians} \]

Problem 3.3

\[ L = W = 35 \, \text{kN} \implies 35 \times 10^6 \times (N) \]

\[ U = 300 \times \frac{3.6}{3.6} = 88.3 \, \text{m/s}, \quad \rho = 1.225 \, \text{kg/m}^3, \quad S = 20 \, \text{m}^2, \quad AR = \frac{b^2}{S} = 11.25 \]

\[ b = 15 \, m, \quad a_0 = 271, \quad \alpha_{\text{span}} = 4^\circ \times \frac{180}{\pi} = 0.07 \, \text{rad} \]

\[ * \text{constant downwash} \implies \text{elastic wing} \]

\[ C_L = \frac{a_0 (\alpha - \alpha_{\text{span}})}{1 + a_0 \frac{S}{\pi AR}} = 0.44 \]

\[ C_{D} = \frac{C_L^2}{\pi AR} = 0.004 \]

\[ \text{where} \]

\[ C_L = \frac{L}{\rho U^2 S} = \frac{35 \times 10^6}{0.5 \times 1.225 \times 83.2 \times 285} = 0.4 \]
Problem 4.2

a) Aerodynamic Heating:
1. The moving fluid has a certain of kinetic Energy
2. The fluid flow over surface, its velocity decrease due to friction, the kinetic Energy also decrease.
3. The lost of kinetic Energy reappear in form of Internal Energy.
4. The warmer fluid will start heat the surface.

b) Skin friction due to skin drag.
Pressure drag due to separation.

c) Skin friction:

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<tr>
<td>Heat flow</td>
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</tbody>
</table>


d) Flaps will change pressure distribution and increasing the chamber airfoil. Also allow to increase lift and flap will start from leading edge.
a) Low pressure, because its near to root

Rehdon and it's also related with thickness. Also, some value will be negative value.

b) Single point: it's enough to meet one operation point design. Ex: given C, AR ---

- Multi point: The design must meet satisfactory at performance two or more condition & to reduce structural weight and improve stalling characteristic.

c) We will need skin friction drag & heat transfer also the max lift.

d) The load should be equal along the airfoil and chord distribution should produce to additional load distribution.
Problem 6
a) at first cruise condition should mean.
   the design wing perimeter will be strongly by selection
   aho here we have long span its make know drag
   
   x

b) Ar ratio is high because $C_l$ is max.

   ✓

c) because after this high altitude the density
   its so less $V_2$ from see level. Also can't
   controll the plane.
   x
Supported Program Outcomes (c)
5.1 **Outcome Definition and Outcome Indicators**

Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints.

| c.1 | Correctly Describe the problem with clear objectives that are complete, specific, and concise including identification of customer needs and transforming them into design requirements.
| c.2 | Plan an effective design strategy including a plan of attack, decomposition of work into subtasks, development of a timetable.
| c.3 | Develop several potential solutions and compares them to find the best baseline.
| c.4 | Develop solutions that include economic, safety, environmental and other realistic constraints.
| c.5 | Integrate prior knowledge of mathematics, science, and engineering principles to the design problem.
| c.6 | Use computer tools and engineering resources effectively.
| c.7 | Define practical measures of effectiveness and use economic and other constraints to correctly optimize the baseline design.
| c.8 | Evaluate the solution by comparing the performance of the final design to customer demands and existing products if any.
| c.9 | Support design procedure with documentation and references.

5.2 **Course Learning Objectives addressing the outcome**

[Table or diagram showing course learning objectives and assessment tools]
### 5.3 Outcome Survey

#### Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints.

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPICABILITY</th>
<th>Poor</th>
<th>Fair</th>
<th>Adequate</th>
<th>Good</th>
<th>V. Good</th>
<th>Excellent</th>
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<tbody>
<tr>
<td>c.1</td>
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</tbody>
</table>

No. of Attributes: 10
5.4 Outcome Assessment and Improvement Report

[Graphs and tables related to outcome assessment and improvement]
5.5  **Students Work Samples**
Insert here at least 3 students’ work samples (assignments) that address this outcome that you have evaluated using the rubric of the outcome under consideration. You have to attach the filled rubric to each work sample similar to what was done in divider 3 for outcome “a”
Supported Program
Outcomes (e)
7.1 **Outcome Definition and Outcome Indicators**

**Outcome (e): an ability to identify, formulate, and solve engineering problems**

| e.1 | Capture essential information and distinguish them from extraneous data. |
| e.2 | Consistently and efficiently apply engineering principles with no conceptual errors and few if any procedural errors. |
| e.3 | Recognize the absence of necessary information and make reasonable approximations. |
| e.4 | Present easy-to-follow steps which are logical and adequately detailed. |
| e.5 | Reach correct and reasonable solutions. |

7.2 **Course Learning Objectives addressing the outcome**
### Outcome Survey

**Course Level Survey**

**Course (AE-311) - Section (01) - Semester (Spring) - Year 2008/2009**

**DEPARTMENT OF Aeronautical Engineering**

**Indirect Assessment of Program Outcomes**

**Outcome (e): an ability to identify, formulate, and solve engineering problems**

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>Applicability</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.1</td>
<td></td>
<td>Read and understand the information given about a problem?</td>
</tr>
<tr>
<td>e.2</td>
<td></td>
<td>Define a problem in ways you can understand it (build up a clear picture in your mind of the different parts of the problem and the significance of each part)?</td>
</tr>
<tr>
<td>e.3</td>
<td></td>
<td>Research and gather information pertaining to the problem?</td>
</tr>
<tr>
<td>e.4</td>
<td></td>
<td>Use a process, as well as a variety of tactics and approaches to tackle (real world) problems?</td>
</tr>
<tr>
<td>e.5</td>
<td></td>
<td>Monitor your problem-solving process and occasionally reflect upon its effectiveness?</td>
</tr>
<tr>
<td>e.6</td>
<td></td>
<td>Focus on accuracy rather than speed when you solve problems?</td>
</tr>
<tr>
<td>e.7</td>
<td></td>
<td>Write down ideas, create charts / figures to help overcome the storage limitations of short-term?</td>
</tr>
<tr>
<td>e.8</td>
<td></td>
<td>Be organized and systematic when you solve problems?</td>
</tr>
<tr>
<td>e.9</td>
<td></td>
<td>Be flexible in the application of a problem-solving strategy (keep options open, view a situation from many different perspectives / points of view)?</td>
</tr>
<tr>
<td>e.10</td>
<td></td>
<td>Draw on the pertinent subject knowledge and critically assess the quality and accuracy of that knowledge / data?</td>
</tr>
<tr>
<td>e.11</td>
<td></td>
<td>Take risks, cope with ambiguity, welcome change and manage stress, when you solve problems?</td>
</tr>
<tr>
<td>e.12</td>
<td></td>
<td>Use an overall approach that emphasizes fundamentals rather than trying to combine various memorized sample solutions?</td>
</tr>
</tbody>
</table>

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course

| No. of Attributes | 12 |
7.4 Outcome Assessment and Improvement Report
7.5  **Students Work Samples**
Insert here at least 3 students’ work samples (assignments) that address this outcome that you have evaluated using the rubric of the outcome under consideration. You have to attach the filled rubric to each work sample similar to what was done in divider 3 for outcome “a”
Supported Program
Outcomes (g)
9.1 **Outcome Definition and Outcome Indicators**

**Outcome (g): an ability to communicate effectively**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>g.1</td>
<td>Present correct technical information written at the appropriate level for the intended reader.</td>
<td></td>
</tr>
<tr>
<td>g.2</td>
<td>Prepare correctly formatted documents that contain few, if any, typographical or grammatical errors.</td>
<td></td>
</tr>
<tr>
<td>g.3</td>
<td>Prepare well organized documents which contain an introduction that interests and orients a reader, a body that is relevant and covers important points and conclusions with summary and recommendations, when appropriate.</td>
<td></td>
</tr>
<tr>
<td>g.4</td>
<td>Present authentic work with references that credit work from other sources.</td>
<td></td>
</tr>
<tr>
<td>g.5</td>
<td>Deliver efficient oral presentations that maintain audience interest.</td>
<td></td>
</tr>
<tr>
<td>g.6</td>
<td>Make effective use of visual aids during oral presentations.</td>
<td></td>
</tr>
<tr>
<td>g.7</td>
<td>Prepare well-organized presentations which contain an introduction that interests and orients the audience, a body that is relevant and covers important points and conclusions with recommendations, when appropriate.</td>
<td></td>
</tr>
<tr>
<td>g.8</td>
<td>Use allotted time appropriately when delivering an oral presentation.</td>
<td></td>
</tr>
<tr>
<td>g.9</td>
<td>Demonstrate self confident in answering questions correctly and completely during oral presentations.</td>
<td></td>
</tr>
</tbody>
</table>

9.2 **Course Learning Objectives addressing the outcome**

![Course Learning Objectives chart](chart.png)
## 9.3 Outcome Survey

**DEPARTMENT OF Aeronatical Engineering**  
Indirect Assessment of Program Outcomes  
Course Level Survey  
**COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009**

### Outcome (g): an ability to communicate effectively

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>g.1</td>
<td>Produce well-organized reports, following guidelines?</td>
</tr>
<tr>
<td>g.2</td>
<td>Use clear and correct language and terminology while describing experiments, projects, or solutions to engineering problems?</td>
</tr>
<tr>
<td>g.3</td>
<td>Describe accurately in a few paragraphs a project / experiment performed, the procedure used, and the most important results when writing abstracts or summaries?</td>
</tr>
<tr>
<td>g.4</td>
<td>Give well-organized presentations, following guidelines?</td>
</tr>
<tr>
<td>g.5</td>
<td>Use visuals to convey their message effectively, when making presentations?</td>
</tr>
<tr>
<td>g.6</td>
<td>Present the most important information about a project / experiment, while staying within my allotted time when making presentations?</td>
</tr>
</tbody>
</table>

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course

<table>
<thead>
<tr>
<th>Attributes</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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**9.2**
9.4 Outcome Assessment and Improvement Report

<table>
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<th>OUTCOME ATTRIBUTES</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>AVERAGES</th>
<th>9.4</th>
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<tr>
<td>Present content in a logical sequence...</td>
<td></td>
<td></td>
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<tr>
<td>Prepare written assignments based on the appropriate level for the student...</td>
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<td></td>
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<td>83</td>
<td>3</td>
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<tr>
<td>Prepare oral presentations using visuals to enhance understanding,...</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>73</td>
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<tr>
<td>Prepare and organize written documents which contain an introduction that...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83</td>
<td>3</td>
</tr>
<tr>
<td>Prepare well-organized presentations which contain an introduction that...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>73</td>
<td>5</td>
</tr>
<tr>
<td>Use alloted time appropriately when delivering oral presentations...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>73</td>
<td>5</td>
</tr>
<tr>
<td>Demonstrate self-confidence in answering questions...</td>
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<td>73</td>
<td>5</td>
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</table>

PROGRAM OUTCOME

<table>
<thead>
<tr>
<th>PROGRAM OUTCOME</th>
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<tbody>
<tr>
<td>No. OF STUDENTS</td>
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<tr>
<td>AVERAGE CLASS ACHIEVEMENT ON THE PROGRAM OUTCOME</td>
<td>3.0</td>
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</tbody>
</table>
9.5  Students Work Samples
Insert here at least 3 students’ work samples (assignments) that address this outcome that you have evaluated using the rubric of the outcome under consideration. You have to attach the filled rubric to each work sample similar to what was done in divider 3 for outcome “a”
Supported Program
Outcomes (j)
12.1 Outcome Definition and Outcome Indicators

Outcome (j): A knowledge of contemporary issues

| 
| --- |
| j.1 | Identify contemporary issues (e.g. bioethics, energy crises, terrorism, global warming, globalization, pollution, mobile technology and communications, information management and security) and explain their impact and what makes them particularly problematic or controversial in the present time. |
| j.2 | Suggest reasonable theories regarding the root causes of contemporary problems. |
| j.3 | Identify possible solutions to contemporary problems, as well as any limitations of such strategies. |

12.2 Course Learning Objectives addressing the outcome

[Graphical representation of course learning objectives and assessment tools]
### 12.3 Outcome Survey

**Outcome (j): a knowledge of contemporary issues**

N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
</tr>
</thead>
<tbody>
<tr>
<td>j.1</td>
<td>Identify contemporary issues (ex. bioethics, market and workforce globalization, mobile technology and communications, information management and security) and explain what makes them particularly problematic or controversial in the present time?</td>
</tr>
<tr>
<td>j.2</td>
<td>Suggest reasonable theories regarding the root cause(s) of contemporary problems?</td>
</tr>
<tr>
<td>j.3</td>
<td>Identify possible solutions to contemporary problems, as well as any limitations of such strategies?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of Attributes</th>
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</table>

**Attributes**

<table>
<thead>
<tr>
<th>Poor</th>
<th>Fair</th>
<th>Adequate</th>
<th>Good</th>
<th>V. Good</th>
<th>Excellent</th>
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<tr>
<td>0</td>
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<td>2</td>
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</table>

**Indirect Assessment of Program Outcomes**

**Course Level Survey**

COURSE (AE-311) - SECTION (01) - SEMESTER (Spring) - YEAR 2008/2009
12.4 Outcome Assessment and Improvement Report
12.5 Students Work Samples
Insert here at least 3 students’ work samples (assignments) that address this outcome that you have evaluated using the rubric of the outcome under consideration. You have to attach the filled rubric to each work sample similar to what was done in divider 3 for outcome “a”
Supported Program Outcomes (k)
13.1 Outcome Definition and Outcome Indicators

Outcome Definition: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- k.1 Apply engineering principles to formulate problems without conceptual errors.
- k.2 Apply calculus, differential equations, algebra, and advanced math techniques to solve engineering problems.
- k.3 Use discipline related commercial packages. Present work documents that are word processed, clear, and contain well integrated computer-made graphs, figures, and illustrations that enhance comprehension.
- k.4 Use discipline related modern non-conventional measuring instruments efficiently.
- k.5 Devise and maintain user-friendly web pages with helpful graphics and frequent updates. Use the internet to gather and disseminate information.
- k.6 Demonstrate competence in discipline related professional practices

13.2 Course Learning Objectives addressing the outcome
### 13.3 Outcome Survey

**Outcome(k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice**

**N.B. Attributes marked NA by the instructor, in the second column, are not addressed in the course.**

<table>
<thead>
<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>To which extent, in this course, you:</th>
<th>Poor</th>
<th>Fair</th>
<th>Adequate</th>
<th>Good</th>
<th>V. Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>k.1 NA</td>
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<table>
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<tr>
<th>OUTCOME ATTRIBUTES</th>
<th>APPLICABILITY</th>
<th>How do you rate the contribution of this course to increase your ability to do the following?:</th>
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</thead>
<tbody>
<tr>
<td>k.2 NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>k.3</td>
<td>Use Word and Excel to produce high quality technical reports?</td>
<td></td>
</tr>
<tr>
<td>k.4</td>
<td>Use state-of-the-art technology for engineering system design, control, and analysis?</td>
<td></td>
</tr>
<tr>
<td>k.5</td>
<td>Use Power Point to give high quality oral presentations?</td>
<td></td>
</tr>
<tr>
<td>k.6</td>
<td>Use computer simulations to conduct parametric studies?</td>
<td></td>
</tr>
<tr>
<td>k.7</td>
<td>Use computer simulations to perform optimization?</td>
<td></td>
</tr>
<tr>
<td>k.8</td>
<td>Use computer simulations to perform what if explorations?</td>
<td></td>
</tr>
<tr>
<td>k.9</td>
<td>Use computer simulations to perform optimization?</td>
<td></td>
</tr>
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</table>

**No. of Attributes**: 7
13.4 Outcome Assessment and Improvement Report
13.5 Students Work Samples
Insert here at least 3 students’ work samples (assignments) that address this outcome that you have evaluated using the rubric of the outcome under consideration. You have to attach the filled rubric to each work sample similar to what was done in divider 3 for outcome “a”