University: Cairo **Faculty:** Engineering **Department:** Aerospace Engineering

Course Specifications

Program: Aerospace Engineering
Major Field: Aerodynamics
Department: Aerospace Engineering Department
Academic Year Level: Third Year Undergraduate
Term: Second Term
Year of Approval: March 2015.

A- Basic Information

Title: Boundary Layer
Code: AER301B
Credit Hours: 3
Weekly Hours: Lectures 3, Tutorials 1, Total 4
Prerequisite Courses: AER301A

B-Professional Information

1-Overall Aims of Course

Introduce the student to the concept of the boundary layer and hence the splitting of the flow into an outer inviscid region and an inner viscous region, to compute the drag and heat transfer on a bluff streamlined object.

2-Intended Learning Outcomes

A-Knowledge and Understanding

Upon completion of this course the student should be able to:

- Understand the basic concept of the boundary layer, and splitting of an inner and outer domain
- Understand the various assumptions applied to obtain the boundary layer approximation
- Understand the basic theory of flow control

B-Intellectual Skills

Upon completion of this course the student should be able to:

- Apply exact methods to compute the boundary layer development and surface friction drag for flat plates with laminar flow
- Apply approximate methods to compute the boundary layer development and surface friction drag on streamlined bodies in laminar flow
- Solve problems with a mixed laminar/turbulent boundary layer

- Apply a numerical scheme to compute the boundary layer development on arbitrary airfoil shapes, coupling the viscous and inviscid flow solutions
- Apply a flow control procedure, to design fully laminar non separated airfoils
- Apply the boundary layer theory to compute the heat transfer from laminar bluff bodies

C-Professional and Practical Skills

Upon completion of this course the student should be able to

- Analyze boundary layers for various aircraft components
- Analyze urban and atmospheric boundary layers
- Apply various flow control techniques to stabilize the laminar boundary layer and avoid separation

3-Course Contents

Topic	Lecture Hour	Tutorial Hour
Chapter 1: Introduction	**6**	**2**
Introduction		
The development of the boundary layer		
Velocity Profile		
Estimation of the boundary layer thickness		
Boundary layer types		
Effects of external pressure gradient		
Boundary layer separation		
Displacement thickness		
Momentum thickness		
Kinetic energy thickness		
Local shear stress and surface friction drag		
Chapter 2: Laminar Boundary Layer	**8**	**3**
Prandtl Boundary Layer Equations		
Exact Blasius solution		
Boundary layer thickness		
Displacement thickness		
Momentum thickness		
Kinetic energy thickness		
Velocity profile in boundary layer		
Local shear stress at surface		
Experimental evidence		
Chapter 3: Exact Solutions for the Boundary Layer Equations	**2**	**0**
Flow past a wedge		

Two dimensional stagnation flow		
Similarity solutions for the laminar boundary layer		
Chapter 4: The Momentum Integral Equation	**6**	**2**
Von Karman Integral equation		
Special Case: Flat plate and no suction		
Approximate Velocity Profiles		
Some Applications of Momentum Integral Equation		
Chapter 5: Turbulent Flow	**6**	**2**
Reynolds Stress		
Turbulent velocity profile		
Rate of growth of the turbulent boundary layer		
Mixed boundary layer on a flat plate		
Calculation of transition length		
Calculation of skin friction drag		
Effect of surface roughness		
Chapter 6: Heat Transfer In Laminar Boundary Layers	**4**	**2**
Introduction		
Formulation of governing equations		
Chapter 6: Computational Methods	**6**	**2**
Laminar flow		
Turbulent flow		
Chapter 7: Flow Control	**6**	**2**
Motion of the solid wall		
Acceleration of the boundary layer		
Suction		
Laminar airfoils		
Airfoil cooling and heating		
Revision	**0**	**2**

4-Teaching and Learning Methods

- Board instructions
- Student discussions
- Homework problems
- Project assignment
- Discussion of exercise problems

5-Student Assessment Methods

- Unannounced quizzes
- Reports of exercise problems to assess understanding of solution methods
- Mid-term exam to assess material comprehension
- Project submission and oral exam
- Final exam to assess overall material comprehension

Assessment Schedule

Assessment 1	Random
Assessment 2	3 homework assignments/semester
Assessment 3	8th week of the semester
Assessment 4	13th week of the semester
Assessment 4	15th week of the semester

Weighting of Assessments

Homeworks and quizzes	10%
Project and oral exam	15%
Mid-Term exam	15%
Final exam	60%

6-List of References

6-1 Course Notes

Elhadidi, B., "Boundary Layer Theory", Aerospace Department, Faculty of Engineering, Cairo University.

6-2 Essential Textbooks

E.L. Houghton, and N.B. Carruthers, "Aerodynamics for Engineering Students", 4th Edition, John Wiley and Sons, 1993.

Schlichting, H., "Boundary Layer Theory", Springer Verlag, 10th Ed., 2002.

Kays, W.M, and Crawford, M.E., "Convective Heat Transfer", 3rd Edition, McGraw-Hill, 1993.

7-Facilities Required for Teaching and Learning

- Board
- Course notes
- Exercise sheets

- Department library

Course Coordinator: Dr. Basman Elhadidi
Head of Department: Prof. Ayman H. Kassem
Date: March, 2015.