# Fundamentals of Incompressible Aerodynamics

| Semester No | Code | Credit Hours |
|---|---|---|
| 3 | AE-215 | 3-1 |

**COURSE DESCRIPTION:**

This is the first course in Aerodynamics, which covers the fundamentals of fluid mechanics and incompressible aerodynamics. It deals with incompressible fluid flow only and comprises two major parts. The first part includes the concepts of fluid dynamics. In this part the fluid flows are analyzed, and mass flow rate, forces and energy flux are calculated. It also covers elementary flows and their superposition. The second part deals with 2D airfoil characteristics, thin airfoil theory, wing characteristics, Prandtl's lifting line theory and general lift distribution. Understanding of lift and drag characteristics of the wing is also discussed in the later part of this course.

**TEXT AND MATERIAL**

**Textbooks:**

1) "Fundamentals of Aerodynamics" by John D. Anderson, McGraw Hill, NY, 6$^{th}$Edition, 2017
2) "Fluid Mechanics" by Frank M White McGraw Hill, NY, 8$^{th}$ Edition, 2016

**Reference Material:**

1. "Aerodynamics for Engineering Students" by E.L. Houghton, PW Carpenter,BH, 7$^{th}$ Edition, 2016.
2. "Introduction to Flight" by John D. Anderson, McGraw-Hill, NY, 8$^{th}$ Edition,2016

**PREREQUISITE:**

1. AE-101 : Introduction to Aerospace Engineering

**COURSE LEARNING OUTCOMES:**

Upon successful completion of the course, the student should be able to:

| S No | CLO Statement | PLO | Learning Domain and level |
|---|---|---|---|
| 1 | **Understand** and derive governing equations of fluid flow and identify tools for basic understanding for incompressible, irrotational and viscous flows | 1 | C2 |
| 2 | **Analyze** inviscid flow using elementary flows and its superposition. | 2 | C4 |
| 3 | **Analyze** the aerodynamics of 2-D Airfoil and wing using potential flow theory. | 2 | C4 |
| 4 | **Analyze** viscous flows for laminar and turbulent boundary layer. | 2 | C3 |
| 5 | Use the experimental apparatus to comprehend fluid flow phenomenon (e.g., airflow over airfoil, vortex flows etc.) and to **measure** flow parameters. | 5 | P3 |

**ASSESSMENT SYSTEM:**

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|---|---|
| Quizzes | 10-15% |
| Assignments | 5-10% |
| OHTs | 30-40% |
| ESE | 40-50% |

## TOPICS COVERED WITH THEIR CONTRIBUTION TO PLOs:

| Week No | Description | Ref | Quizzes | Assignment | CLO No |
|---|---|---|---|---|---|
| 1 | **Types of Flows**<br>Continuum versus Free Molecular Flow<br>Inviscid versus Viscous Flow<br>Incompressible versus Compressible Flow | Text 1 / 1.10 | 02 | 01 | 1 |
| 2 | **Fluid Statics**<br>Buoyancy force<br>Manometer<br>Application, Review of<br>Vector Relations | Text 1 / 1.9<br>Text 1 / 2.2 | | | |
| 3 | Models of the Fluid : Control Volumes and Fluid Elements, Dynamics of Fluid Flow (Reynolds TransportTheorem) | Text 1 / 2.3<br>Text 2 / 3.2 | | | |
| 4 | **Conservation of Mass** Control Volume/ Integral Form<br>Differential Form | Text 1 / 2.4<br>Text 2 / 3.3 | | | |
| 5 | **Linear Momentum Equation**<br>Control Volume / Integral Form<br>Differential Form<br>Bernoullis Equation, **Energy Equation**<br>Control Volume / Integral Form Differential form,<br>Accelerated Field: Material Derivative,<br>**Flow Visualization** Pathlines Streamlines<br>Streaklines | Text 1 / 2.5<br>Text 2 / 3.4, 3.7<br>Text 1 / 2.7<br>Text 2 / 3.6<br>Text 1 / 2.11 | | | |
| 6 | **Fundamentals of Incompressible and Irrotational Flow**<br>Angular Velocity &<br>VorticityStrain and<br>Circulation Stream<br>Function<br>Velocity Potential<br>Governing Equation for Incompressible and Irrotational Flow<br>Laplace Equation | Text 1 / 2.12-2.16<br>Text 1 / 3.6-3.7 | | | |

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|---|---|---|---|---|---|
| 7 | **OHT-1** | | | | |
| 8 | **Elementary Flows**<br>Uniform Flow<br>Source / Sink Flow<br>Doublet Flow<br>Vortex Flow<br>Vortex Sheet | Text 1 / 3.8-3.14<br><br>Text 2 / 8.3 | | | 2 |
| 9 | Introduction to viscous flows<br>The Navier-Stokes Equations<br>Illustrative examples of viscous flows<br>Boundary Layer Equations<br>Laminar and Turbulent Boundary layers | Text 1 / 15.2 - 15.4 16.1-16.3, 16.5<br><br>Text 2 / 4.10<br>Text 1 / 17.1-17.3 18.1-18.2 19.2 | 02 | 01 | 4 |
| 10 | Aerodynamic Forces and Moments<br>Dimensional Analysis and Buckingham Pi Theorem<br>Flow Similarity | Text 1 / 1.5<br>Text 1 / 1.7<br>Text 1 / 1.8 | | | |
| 11 | Characteristics of Airfoil<br>High Lift Devices<br>Incompressible Flow over Airfoils<br>Kutta Condition<br>Kelvin Circulation Theorem Starting Vortex | Text 1 / 4.5-4.6 | | | |
| 12 | Thin Airfoil Theory (Symmetric Airfoil)<br>Thin Airfoil Theory (Cambered Airfoil) | Text 1 / 4.7<br>Text 1 / 4.8 – 4.9 | | | |
| 13 | **OHT-2** | | | | |
| 14 | Wing Characteristics<br>Introduction to Downwash & Induced Drag<br>Curved vortex filament, BiotSavart Law, Helmholtz’s Vortex theorem | Text 1 / 5.1<br>Text 1 / 5.2 | | | |
| 15 | Introduction to Prandtl’s Lifting Line theory | Text 1 / 5.3 | 02 | 01 | 3 |
| 16 | Results of general & elliptical lift distributions and Effect of Aspect Ratio | Text 1 / 5.3.1-5.3.3 | | | |
| 17 | Revision | | | | |
| 18 | **END SEMESTER EXAMINATION** | | | | |

**Practical**

| Lab Class | Exp. No. | Description | CLO No. |
|---|---|---|---|
| 1. | 1. | To calculate head loss in straight pipe for laminar and turbulentflows (Laminar and Turbulent Pipe flow Apparatus) | 5 |
| 2. | 2. | Pressure losses in Fittings (Axial Fan Flow Apparatus) | |
| 3. | 3. | To determine the relationship between head loss due to fluid friction and velocity for flow of water through smooth borepipes (Fluid Friction Apparatus) | |
| 4. | 4. | To determine the drag coefficient of a blade at different anglesof attack (Air Bench Apparatus) | |
| 5. | 5. | To determine the lift and drag characteristics of NACA-0012 airfoil and a right circular cylinder with the help of open circuit subsonic wind tunnel(OCWT) | |
| 6. | 6. | To determine drag coefficient of cylinder (Air Bench Apparatus) | |
| 7. | 7. | To determine drag coefficient around smooth and roughspherical objects in open circuit wind tunnel (OCWT) | |
| 8. | 8. | To determine the velocity profile behind a body (Wake depression) (Air Bench Apparatus) | |
| | 9. | To determine the velocity profile and the boundary layer on asmooth flat plate (Air Bench Apparatus) | |
| 9. | 10. | To determine the velocities at the inlet and exit of the convergent nozzle (Axial Fan Flow Apparatus) | |
| 10. | 11. | To determine the velocity profile and the boundary layer on arough flat plate (Air Bench Apparatus) | |
| 11. | 12. | To determine the pressure and velocity distribution along the radius of a forced vortex (Forced Vortex Apparatus) | |
| | 13. | To study shock waves around various aerodynamic bodies in Supersonic Wind Tunnel (SSWT) | |
| 12. | 14. | Hydrostatic Bench in Flow Visualization Lab Osborne Reynold Equipment (Laminar-Turbulent Pipe Flow) | |
| 13. | 15. | Velocity Calibration and Angle of attack Calibration for wind tunnel testing (OCWT) | |
| 14. | 16. | Force and moment calibration for wind tunnel testing and Wind tunnel Correction (OCWT) | |
| 15. | 17. | Testing of aircraft models to determine lift curve slope and drag polar in wind tunnel. (OCWT) | |
| 16. | 18. | Calculation and comparative analysis of performance and stability of aircraft models. (OCWT) | |
| 17. | 19. | Open Ended Lab | |
| 18. | 20. | End Semester Exam | |