INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**AERODYNAMICS – I**			
Course Code	**A42102**			
Regulation	**R13 – JNTUH**			
Course Structure	**Lectures**	**Tutorials**	**Practical's**	**Credits**
	4	1	-	4
Course Coordinator	Dr. A. Barai, Professor			
Team of Instructors	Dr. A. Barai, Professor			

I. COURSE OVERVIEW:

Aerodynamics extends fluid mechanic concepts to the aerodynamic performance of wings and bodies in sub/supersonic regimes. The course has four components: (i) subsonic potential flows, including source/vortex panel methods; (ii) viscous flows, including laminar and turbulent boundary layers; (iii) aerodynamics of airfoils and wings, including thin airfoil theory, lifting line theory, and panel method/interacting boundary layer methods; (iv) introduction to properller. Aerodynamics is the study of the flow of air about a body. In this case, the body will be an airplane, but much of the aerodynamics in this course is relevant to a wide variety of applications from sail boats to automobiles to birds. The course should help students to: formulate and apply appropriate aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations; assess the applicability of aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations and estimate the errors resulting from their application; perform a computational and experimental aerodynamic analysis and design.

II. PREREQUISITE(S)

Level	Credits	Periods/ Week	Prerequisites
UG	3	5	Basic concepts of Physics , Advanced Mathematics

III MARKS DISTRIBUTION

Sessional Marks	University End Exam marks	Total marks
Mid Semester Test There shall be two midterm examinations. Each midterm examination consists of subjective type and objective type tests. The subjective test is for 10 marks of 60 minutes duration. Subjective test of shall contain 4 questions; the student has to answer 2 questions, each carrying 5 marks. The objective type test is for 10 marks of 20 minutes duration. It consists of 10 Multiple		

choice and 10 objective type questions, the student has to answer all the questions and each carries half mark.	75	100
First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion **Assignment** Five marks are earmarked for assignments. There shall be two assignments in every theory course. Marks shall be awarded considering the average of two assignments in each course.		

IV. EVALUATION SCHEME

S. No	Component	Duration	Marks
1.	I Mid Examination	80 minutes	20
2.	I Assignment	-	5
3.	II Mid Examination	80 minutes	20
4.	II Assignment	-	5
5.	External Examination	3 hours	75

V. COURSE OBJECTIVES:

1. **Understand** basic philosophy & ideas of flow
2. **Understand** the physics behind the Governing Equations and flow models
3. **Identify** theory behind the forces and moments
4. **Discuss** the application of aerodynamics in various engineering discipline
5. **Understand** the concept of boundary layer flows and impact
6. **Analyze** the inviscid flow properties
7. **Discuss** the propeller aerodynamics.

VI. COURSE OUTCOMES:

At the end of the course the students are able to:

1. **Apply** knowledge and understand the essential facts, concepts and principles of aerodynamics.
2. **Apply** the basic knowledge in mathematics, science and engineering.
3. **Analyze** the inviscid flow properties
4. **Analyze** the boundary layer flows
5. **Analyze** how the aerodynamics affects the aircraft design and operation
6. **Analyze** the concept of lifting line theory.
7. **Analyze** the elliptic load distribution.
8. **Evaluate** the source and vortex panel method for aerofoils.
9. **Analyze** the flow over a propeller.
10. **Analyze** and understand the lift augmentation techniques.

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program Outcomes		Level	Proficiency assessed by
PO1	Knowledge in fundamentals of mathematics, science and engineering.	H	Assignments
PO2	An ability to identify, formulate and solve problems in key areas of Aerodynamics, Structures, Propulsion, Flight Dynamics and Control, Design, Testing, Space and Missile Technologies and Aviation of Aeronautical Engineering discipline.	H	Assignments
PO3	An ability to design and conduct experiments, analyze and interpret data related to various areas of Aeronautical Engineering.	S	--
PO4	An ability in conducting investigations to solve problems using research based knowledge and methods to provide logical conclusions.	H	Designing, Exercises
PO5	Skills to use modern engineering and IT tools, software and equipment to analyze the problems in Aeronautical Engineering.	S	Designing
PO6	Understanding of impact of engineering solutions on the society to assess health, safety, legal, and social issues in Aeronautical Engineering.	N	--
PO7	The impact of professional engineering solutions in environmental context and to be able to respond effectively to the needs of sustainable development.	N	--
PO8	The knowledge of Professional and ethical responsibilities.	N	Prototype Models
PO9	An ability to work effectively as an individual and as a team member/leader in multidisciplinary areas.	S	--
PO10	An ability to critique writing samples (abstract, executive summary, project report), and oral presentations.	S	Document Preparation,
PO11	Knowledge of management principles and apply these to manage projects in multidisciplinary environments.	N	Assignments
PO12	The need of self education and ability to engage in life - long learning.	H	Assignments

N = None **S = Supportive** **H = Highly Related**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

PROGRAM SPECIFIC OUTCOMES		LEVEL	PROFICIENCY ASSESSED BY
PSO 1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	H	Lectures and Assignments
PSO 2	**Problem solving skills:** imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles	S	Tutorials
PSO 3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	H	projects
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats	S	Seminars and Projects

N-None **S-Supportive** **H-Highly Related**

IX. SYLLABUS

UNIT I

Review of Fluid Mechanics: Importance of Aerodynamics, Fundamental aerodynamics variables and dimensional analysis (statement of Buckingham π theorem.) leading to force & moment coefficient and dimensionless similarity such as Reynolds number, Mach number, incompressible flow, compressible flow and Mach number. Continuity & Momentum equations in differential form. Euler equation, viscosity, Navier-Stokes equation Reynolds as an order-of-magnitude measure of ratio of inertia forces to viscous forces.

UNIT II

Inviscid Incompressible flows: Large Reynolds number flows, Prandtl's Boundary Layer Hypothesis, viscous boundary layer flow and inviscid external flow. Justification of inviscid flow analysis. Angular Velocity, Vorticity and circulation, Kelvin Theorem and irrotational flow velocity potential, Stream function, Laplace equation, boundary condition at infinity and wall, Elementary flows and their combinations. Flow past circular cylinder non lifting case, lifting case & Magnus effect, the spinning tennis ball, D' AIembert's Paradox, Kutta Joukowsky theorem - circular cylinder with vortex, airfoil as arbitrary cylinder with a sharp trailing edge, Kutta condition. Kelvin's circulation theorem & starting vortex, concept of small perturbation & thin airfoil theory — linearization of the boundary condition, resolution of thin airfoil problem into & non lifting cases, their solutions by method of singularity distribution, the aerodynamic center, the center of pressure, load representation

UNIT III

Viscous Flow and Boundary Layer: Role of viscosity in fluid flow boundary layer growth along a flat plate and nearly flat surface, displacement thickness and patching of inviscid external flow to viscous boundary layer flow, laminar boundary layer, transition and turbulent boundary layer, skin friction drag by integration of tangential stress & pressure drag integration of normal stress, factors influencing boundary layer separation adverse pressure gradient and sharp bending / turning of surface-Real (Viscous) flow and variation of drag coefficient with Reynolds number for Circular cylinder. Real (viscous) flow and importance of skin friction drag for airfoils; Effect of transition and surface roughness on airfoils, N-S equation, Boundary layer approximation, Blasius solution for the flat plate problem; Definition of momentum thickness & derivation of Von Karman's momentum equation.

UNIT IV

Inviscid Flow over Wings & Panel Methods: Vortex filament statement of Helmholtz's vortex theorems, Biot-Savart Law, starting, bound & trailing vortices of wings, Lanchester's experiment, Prandtl's Lifting line theory - downwash and induced drag, Elliptic loading & wings of elliptic platforms, expression for induced drag, minimum induced drag for Elliptic platform. Source and vortex panel methods for airfoils. Replacement of an airfoil by a concentrated vortex at quarter - chord point, importance of three- quarter chord point for discretization, use of quarter chord and three- quarter chord points in vortex panel method for wings.

UNIT V

Applied aerodynamics and introduction to propellers: Critical Mach number & Drag Divergence, drag reduction and lift augmentation - Sweep, winglets, Flaps, slats and vortex generators. Propellers: Concept of slip stream with only axial velocity, Actuator disk theory due to Rankine & Froude power & thrust coefficients, why the propeller is twisted by blade element analysis blade angle, advance ratio and Torque coefficient , efficiency , how to read propeller chart.

TEXT BOOKS:

1. Anderson, J .D; ("Fundamental of Aerodynamics", 5th Edition, Mc Graw-Hill International Edition.
2. E. L. Houghton, P. W. Carpenter; "Aerodynamics for Engineering Students", 5th Edition, Elsevier.

REFERENCES:

1. L. J. Clancy, "Aerodynamics", Sterling book house.
2. Louis M. Milne-Thomson, "Theoretical Aerodynamics", Imported Edition, Dover Publications.

X. COURSE PLAN:

At the end of the course, the students are able to achieve the following course learning outcomes.

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1	**Discuss** Importance of Aerodynamics	Importance of Aerodynamics	T1.1
2	**Define** Fundamental aerodynamics variables	Fundamental aerodynamics variables	T1.1
3	**Define** Dimensional analysis (statement of Buckingham π theorem) leading to force & moment coefficient	Dimensional analysis (statement of Buckingham π theorem) leading to force & moment coefficient	T1.1
4	**Discuss** Dimensionless similarity such as Reynolds number, Mach number	Dimensionless similarity such as Reynolds number, Mach number	T1.1
5	**Define** Incompressible flow, compressible flow and Mach number	Incompressible flow, compressible flow and Mach number	T1.1
6	**Derive** Continuity & Momentum equations in differential form	Continuity & Momentum equations in differential form	T2.2
7	**Derive** Euler equation, viscosity	Euler equation, viscosity	T2.2
8	**Derive** Navier-Stokes equation	Navier-Stokes equation	T2.2
9	**Discuss** Reynolds as an order-of-magnitude measure of ratio of inertia forces to viscous forces	Reynolds as an order-of-magnitude measure of ratio of inertia forces to viscous forces	T2.2
10	**Discuss** Large Reynolds number flows	Large Reynolds number flows	T1.17
11	**Discuss** Prandtl's Boundary Layer Hypothesis	Prandtl's Boundary Layer Hypothesis	T1.17
12	**Analyze** Viscous boundary layer flow and inviscid external flow	Viscous boundary layer flow and inviscid external flow	T1.17
13	**Justify** of inviscid flow analysis	Justification of inviscid flow analysis	T1.17
14	**Derive** Angular Velocity, Vorticity and circulation	Angular Velocity, Vorticity and circulation	T1.2
15	**Discuss** Kelvin Theorem and irrotational flow	Kelvin Theorem and irrotational flow	T1.4
16	**Derive** Velocity potential, Stream function	Velocity potential, Stream function	T1.2
17	**Derive** Laplace equation	Laplace equation	T1.3
18	**Define** Boundary condition at infinity and wall	Boundary condition at infinity and wall	T1.3
19	**Define** Elementary flows and their combinations	Elementary flows and their combinations	T1.3
20	**Discuss** Flow past circular cylinder - non lifting case	Flow past circular cylinder - non lifting case	T1.3

21	**Define** Lifting case & Magnus effect	Lifting case & Magnus effect	T1.3
22	**Analyze** The spinning tennis ball	The spinning tennis ball	T1.3
23	**Discuss** D' AIembert's Paradox	D' AIembert's Paradox	T1.3
24-25	**Discuss** Kutta-Joukowsky theorem - circular cylinder with vortex	Kutta-Joukowsky theorem - circular cylinder with vortex	T1.3
26	**Discuss** Airfoil as arbitrary cylinder with a sharp trailing edge	Airfoil as arbitrary cylinder with a sharp trailing edge	T1.3
27	**Derive** Kutta condition	Kutta condition	T1.3
28-29	**Analyze** Kelvin’s circulation theorem & starting vortex	Kelvin’s circulation theorem & starting vortex	T1.4
30	**Discuss** Concept of small perturbation & thin airfoil theory	Concept of small perturbation & thin airfoil theory	T1.4
31	**Derive** Linearization of the boundary condition	Linearization of the boundary condition	T1.4
32	**Resolve** thin airfoil problem into & non lifting cases, their solutions by method of singularity distribution	Resolution of thin airfoil problem into & non lifting cases, their solutions by method of singularity distribution	T1.4
33	**Discuss** The aerodynamic center, the center of pressure, load representation	The aerodynamic center, the center of pressure, load representation	T1.4
34	**Discuss** Role of viscosity in fluid flow boundary layer growth along a flat plate and nearly flat surface	Role of viscosity in fluid flow boundary layer growth along a flat plate and nearly flat surface	T1.17
35	**Derive** Displacement thickness and patching of inviscid external flow to viscous boundary layer flow	Displacement thickness and patching of inviscid external flow to viscous boundary layer flow	T1.17
36	**Discuss** Laminar boundary layer, transition and turbulent boundary layer	Laminar boundary layer, transition and turbulent boundary layer	T1.17
37-38	**Derive** Skin friction drag by integration of tangential stress & pressure drag integration of normal stress	Skin friction drag by integration of tangential stress & pressure drag integration of normal stress	T2.4
39	**Analyze** Factors influencing boundary layer separation	Factors influencing boundary layer separation	T2.4
40	**Define** Adverse pressure gradient and sharp bending / turning of surface	Adverse pressure gradient and sharp bending / turning of surface	T2.4
41	**Derive** Real (Viscous) flow and variation of drag coefficient with Reynolds number for Circular cylinder	Real (Viscous) flow and variation of drag coefficient with Reynolds number for Circular cylinder	T2.4
42	**Derive** Real (viscous) flow and importance of skin friction drag for airfoils	Real (viscous) flow and importance of skin friction drag for airfoils	T2.4
43	**Analyze** Effect of transition and surface roughness on airfoils	Effect of transition and surface roughness on airfoils	T2.4
44	**Derive** N-S equation	N-S equation	T2.4
45	**Derive** Boundary layer approximation	Boundary layer approximation	T2.4
46	**Derive** Blasius solution for the flat plate problem	Blasius solution for the flat plate problem	T2.4

47	**Define** of momentum thickness & **derive** of Von Karman's momentum equation	Definition of momentum thickness & derivation of Von Karman's momentum equation	T2.4
48	**Define** Vortex filament statement of Helmholtz's vortex theorems	Vortex filament statement of Helmholtz's vortex theorems	T1.5
49-50	**Discuss** Biot-Savart Law, starting, bound & trailing vortices of wings	Biot-Savart Law, starting, bound & trailing vortices of wings	T1.5
51 .	**Discuss** Lanchester's experiment	Lanchester's experiment	T1.5
52	**Analyze** Prandtl's lifting line theory - downwash and induced drag, (Bertin, p. 233)	Prandtl's lifting line theory - downwash and induced drag, (Bertin, p. 233)	T1.5
53	**Derive** Elliptic loading & wings of elliptic platforms	Elliptic loading & wings of elliptic platforms	T1.5
54	**Derive** Expression for induced drag, minimum induced drag for Elliptic platform	Expression for induced drag, minimum induced drag for Elliptic platform	T1.5
55	**Define** Source and vortex panel methods for airfoils	Source and vortex panel methods for airfoils	T1.5
56-57	**Discuss** Replacement of an airfoil by a concentrated vortex at quarter - chord point, importance of three- Quarter chord point for discretization, use of quarter chord and three- quarter chord points in vortex	Replacement of an airfoil by a concentrated vortex at quarter - chord point, importance of three- Quarter chord point for discretization, use of quarter chord and three- quarter chord points in vortex	T1.5
58	**Discuss** Panel method for wings	Panel method for wings	R2.17
59	**Define** Critical Mach number & Drag Divergence	Critical Mach number & Drag Divergence	R2.17
60	**Define** Drag reduction	Drag reduction	R2.17
61	**Discuss** Lift augmentation - Sweep, winglets, Flaps, slats and vortex generators **Discuss** Propellers: Concept of slip stream with only axial velocity	Lift augmentation - Sweep, winglets, Flaps, slats and vortex generators Propellers: Concept of slip stream with only axial velocity	R2.17
62	**Analyze** Actuator disk theory due to Rankine & Froude	Actuator disk theory due to Rankine & Froude	R2.17
63	**Define** Power & thrust coefficients	Power & thrust coefficients	R2.17
64	**Discuss w**hy the propeller is twisted by blade element analysis blade angle	Why the propeller is twisted by blade element analysis blade angle	R2.17
65	**Define** Advance ratio and Torque coefficient, efficiency	Advance ratio and Torque coefficient, efficiency	R2.17
66	**Discuss** how to read propeller chart	How to read propeller chart?	T3.2

XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	H	H	S	N	S	H	N	H	N	S	N	S	H	H	S	S
II	H	H	S	S	N	N	N	N	N	N	N	N	H	H	S	S
III	H	H	S	N	N	N	N	S	N	N	N	N	S	H	H	S
IV	H	H	N	N	N	N	N	S	N	N	N	S	H	H	S	S
V	H	H	N	N	N	N	N	N	N	N	N	S	H	H	N	S
VI	H	H	N	N	N	N	N	S	N	N	N	N	H	H	N	S
VII	H	H	N	N	N	N	N	N	N	N	N	N	H	H	N	S

N -None **S-Supportive** **H-Highly Related**

XII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES:

Course Objectives	Program Outcomes												Program Specific			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
1	H	S	S	S	S	H	N	S	N	S	N	S	H	S	N	S
2	S	H	S	S	S	S	N	H	N	S	N	S	S	H	N	S
3	S	S	S	S	S	H	N	S	N	S	N	S	H	S	N	S
4	S	S	S	S	S	S	N	S	N	S	N	S	S	H	N	S
5	H	S	N	N	N	N	N	N	N	N	N	S	H	H	N	S
6	H	N	N	S	N	N	N	N	N	N	N	S	S	S	N	S
7	S	N	N	H	N	N	N	N	N	N	N	N	H	H	H	S
8	S	H	N	N	N	N	N	N	N	N	N	N	S	H	H	S
9	N	N	H	N	N	N	N	N	N	S	N	N	H	S	S	S
10	H	N	N	N	N	N	N	N	N	S	N	N	S	H	H	S

N-None **S-Supportive** **H-Highly Related**

Prepared by: Dr. A. Barai, Professor

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