J.J COLLEGE OF ENGINEERING AND TECHNOLOGY

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SOWDAMBIKAA GROUP OF INSTITUTIONS

ESTD. 1994

DEPARTMENT OF AERONAUTICAL ENGINEERING

AE3701–WIND TUNNEL TECHNIQUES

QUESTION BANK

R-2021

INSTITUTE VISION & MISSION

VISION:

To become a globally recognized "Centre of Academic Excellence" providing Quality Education to all students.

MISSION:

To provide Quality Education in the fields of Engineering, Management, Information, Technology and other Engineering areas.

DEPARTMENT VISION & MISSION

VISION:

To prepare technically skilled and competent intellectual professional graduates to meet the challenges in the Aerospace industry.

MISSION:

M1: To produce technologically competent graduates to be front-runner in their profession.

M2: To provide state-of-the-art facilities and laboratories so as to enhance excellence in teaching and learning process.

M3: To provide need-based quality training programmes in the field of the Aerospace industry.

M4: Enhance the students' sound knowledge in the latest technologies by organizing technical programs and encouraging students to make them present papers and participate in technical events.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1	Apply knowledge in emerging and varied areas of Aerospace Engineering for higher studies, research, employment and product development.
PEO2	Communicate their skills and have a sense of responsibility to protect the environment and have ethical conduct towards their profession and commitment to serve the society.
PEO3	Exhibit managerial skills and leadership qualities while understanding the need for lifelong learning to be competent professionals.

PROGRAM OUTCOMES (POs):

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions Using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including the design of experiments, Analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex Engineering activities with an understanding of the limitations.
PO6	**The engineer and society:** Apply to reason in formed by the contextual Knowledge to assess societal, health, safety, legal and cultural issues and the Consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and Responsibilities and norms of the engineering practice.

PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in Diverse teams, and in multidisciplinary settings.
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply These to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to Engage in in dependent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs):

PSO1	To analyze, design and develop solutions by applying foundational concepts of Aeronautical engineering.
PSO2	To apply design principles and best practices for developing quality products for scientific and business applications.
PSO3	An engineering acumen in identifying, formulating, analyzing and solving complex engineering problems.

AE3701 **WIND TUNNEL TECHNIQUES** **L T P C**
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COURSE OBJECTIVES:

- To learn the Types of low-speed Wind tunnels and non-dimensional numbers with its applications.
- To learn the Types of high-speed Wind tunnels and with its calibration methods.
- To Understand the Special Wind tunnels and with its calibration methods with its design methods.
- To describe flow visualization techniques and data acquisition methods.
- To understand the functions of various instruments associated with wind tunnel.

UNIT I LOW SPEED WIND TUNNELS 9

Classification –non-dimensional numbers-types of similarities - Layout of open circuit and closed-circuit subsonic wind tunnels – design parameters-energy ratio - HP calculations – Calibration methods.

UNIT II HIGH SPEED WIND TUNNELS 9

Blow down, in draft and induction tunnel layouts and their design features -Transonic, and
supersonic tunnels- peculiar features of these tunnels and operational difficulties - sample design calculations and calibration methods.

UNIT III SPECIAL WIND TUNNEL TECHNIQUES 9

Types of Special Wind Tunnels – Hypersonic, Gun and Shock Tunnels – Design features and
calibration methods- Intake tests – store carriage and separation tests - wind tunnel model design for these tests.

UNIT IV WIND TUNNEL INSTRUMENTATION 9

Instrumentation and sensors required for both steady and unsteady measurements – Force measurements using three component and six component balances – calibration of measuring instruments – error estimation and uncertainty analysis.

UNIT V FLOW VISUALIZATION and NON-INTRUSIVE FLOW DIAGNOSTICS 9

Smoke and Tuft grid techniques – Dye injection special techniques – Oil flow
Visualization and PSP techniques - Optical methods of flow visualization – PIV and Laser Doppler techniques – Image processing and data deduction.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On completion of this course, the students expected to be able to:	
CO1	Explain the uses of various types of tunnels and its losses
CO2	Experiment with calibration of different types of high-speed tunnels
CO3	Make use of various special tunnels and its applications
CO4	Make use of various measurement techniques of instruments of wind tunnel
CO5	Can use various techniques for aerodynamic data generation

CO's – PO's & PSO's MAPPING

Correlation of COs with POs / PSOs

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	-	-	-	-	-	-	-	-	-	2		-
CO2	1	3	-	-	3	-	-	-	-	-	-	-	3	1	-
CO3	1	3	1	1	1	-	-	-	-	-	-	-	3	1	-
CO4	1	2	-	2	3	-	-	-	-	-	-	-	2	-	-
CO5	1	1	1	-	-	-	-	-	-	-	-	-	3	1	1
AVG	**1**	**2.2**	**1**	**1.5**	**2.3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2.6**	**1**	**1**

3 – High; 2 – Medium; 1 – Low; - - No correlation

TEXT BOOKS

1. NAL-UNI Lecture Series 12:" Experimental Aerodynamics", NAL SP 98 01 April 1998
2. Rae, W.H. and Pope, A., "Low Speed Wind Tunnel Testing", John Wiley Publication, 1984

REFERENCE BOOKS

1. Bradsaw "Experimental Fluid Mechanics".Lecture course on Advanced Flow diagnostic techniques 17-19 September 2008-NAL,Bangalore
2. Pope, A., and Goin, L., "High Speed Wind Tunnel Testing", John Wiley, 1985.
3. Rathakrishnan, E., “Instrumentation, Measurements, and Experiments in Fluids,” CRC Press –Taylor & Francis, 2007.
4. Short term course on Flow visualization techniques, NAL,2009

UNIT– I

LOW SPEED WIND TUNNELS

PART–A				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	What is called aero-elastic similarity?	CO1	Understand	Low
2	What is scale effect?	CO1	Understand	Low
3	What is geometrical similarity in wind tunnel testing of model?	CO1	Understand	Low
4	What is boundary layer correction in the test section design of wind tunnel?	CO1	Understand	Low
5	State Buckingham pi theorem.	CO1	Remember	Low
6	Define Froude number and state its significance.	CO1	Remember	Low
7	What is low speed wind tunnel?	CO1	Understand	Low
8	How different parameter are measured using wind tunnel?	CO1	Understand	Medium
9	Write down the types of similarities.	CO1	Understand	Medium

PART–B				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	Derive Mach number and Reynolds number as relevant non-dimensional parameters in the flow over an airfoil from non-dimensional analysis.	CO1	Create	High
2	Define the following non-dimensional numbers: force co-efficient, Euler number, Reynolds number and moment co-efficient. How does the model scale effect influence the wind tunnel results?	CO1	Understand	Medium
3	i) State Buckingham theorem. How is this theorem useful in the experiments using wind tunnels? ii) What is the basic principle behind hot wire anemometer? What are its limitations?	CO1	Understand	Medium
4	A one fifth scale model automobile is tested in a wind tunnel in the same air properties as the prototype. The prototype velocity is 50 km/hr for dynamically similar conditions the model drag is 350N. Find the drag of the automobile and the power in kW required to overcome this drag.	CO1	Create	High
5	Assume that the drag D acting on a spherical object that falls very slowly through a viscous fluid is a function of the object	CO1	Create	High

	diameter, d, the object velocity, V, and the fluid viscosity. Determine with the aid of dimensional analysis, how the drag depends on the object velocity?			
6	i) Explain the process involved in calibrating the wind tunnel. ii) How do you measure the air velocity in a wind tunnel?	CO1	Understand	Medium
7	(i) Explain the working principle of a low-speed wind tunnel with neat sketches. (ii) Explain the five primary components of a wind tunnel.	CO1	Understand	Medium
8	The drag force on a submarine which is moving well below the free surface, is to be determined by a test on a model, which is scaled down to one-twentieth of the prototype. The test is to be carried in a water tunnel. The density and kinematic viscosity of the seawater are 1010 kg/m^3 and 1.3 x 10-6 m^2/s. The water in the tunnel has a density of 988 kg/m^3 and a kinematic viscosity of 0.65 x 106 m^2/s. If the speed of the prototype is 2.6 m/s, then determine the speed of the model and the ratio of the drag force in the prototype to the model.	CO1	Create	High

9	An aircraft is to fly at an altitude of 9 km (where the temperature and pressure are -45°C and 30.2 kPa respectively) at 400 m/s. A 1:20 scale model is tested in a pressurized wind tunnel in which the air is at 15°C. For complete dynamic similarity what pressure and velocity should be used in the wind-tunnel?	CO1	Create	High

UNIT – II

HIGH SPEED WIND TUNNELS

PART–A				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	What are the section loss coefficients?	CO2	Understand	Low
2	Define Froude's number.	CO2	Remember	Low
3	What is turbulence factor of a subsonic wind tunnel?	CO2	Understand	Low
4	How is test section speed measured in case of a subsonic wind tunnel?	CO2	Understand	Low
5	Write down the classifications of wind tunnels.	CO2	Understand	Low
6	Name the factors which influence the design of supersonic tunnels.	CO2	Remember	Low
7	What is induction tunnel?	CO2	Understand	Low
8	What are the various features of transonic and supersonic tunnel?	CO2	Understand	Low
9	Classify the types of wind tunnels.	CO2	Analyze	Medium
10	What is the function of Effuser?	CO2	Understand	Low

PART–B				
Q.No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	Explain the operation the intermittent type supersonic wind tunnel with neat sketches and explain the importance of the second throat.	CO2	Understand	Medium
2	Explain the working principle of a shock tube with a neat sketch.	CO2	Understand	Medium
3	How are the wind tunnels classified? What are the special problems of testing in hypersonic wind tunnels?	CO2	Understand	Medium
4	Sketch the typical layout of a supersonic wind tunnel and mark all the components and subsystems. What is starting problem in supersonic tunnels?	CO2	Create	High
5	With the aid of a neat sketch explain the hypersonic tunnel circuit. How is it different from supersonic tunnel?	CO2	Understand	Medium
6	(i) Explain the working of a supersonic wind tunnel with sketches neat (ii) Write a note on type of nozzle used in a supersonic wind tunnel.	CO2	Understand	Medium
7	(i) What do you understand by wind tunnel effect? (ii) Write a note on operational difficulties in a high-speed wind tunnel.	CO2	Understand	Medium
8	(i) Write the advantages of open return wind tunnels. (ii) Write the disadvantages of open return wind tunnels.	CO2	Understand	Medium

10	(i) Write the advantages of closed return wind tunnels. (ii) Write the disadvantages of closed return wind tunnels.	CO2	Understand	Medium

UNIT – III

SPECIAL WIND TUNNEL TECHNIQUES

PART–A				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	How is turbulence measured in wind tunnels?	CO3	Understand	Low
2	Mention the various types of wind tunnel balances.	CO3	Remember	Low
3	How are wind tunnel balances classified?	CO3	Understand	Low
4	What is the basic principle involved in the interferometer method of flow visualization?	CO3	Understand	Low
5	If the model blockage is more than the allowable limit, what would be its effect?	CO3	Understand	Low
6	Define Strouhal number and state its importance.	CO3	Remember	Low
7	What are the various types of special wind tunnels?	CO3	Understand	Low
8	Define separation test in wind tunnel.	CO3	Remember	Low
9	Define horizontal buoyancy.	CO3	Remember	Low
10	What are the losses in supersonic wind tunnels?	CO3	Understand	Low

PART–B				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	Explain in detail about blockage correction in closed circuit wind tunnels for the wind tunnel calibrations.	CO3	Understand	Medium
2	Explain strut type balance and pyramid type balance.	CO3	Understand	Medium
3	Distinguish between internal and external wind tunnel balances. Briefly explain how force measurements are carried out using an external strain gauge balance.	CO3	Analyze	High
4	Bring out the essential features of a strain gauge based six component internal wind balance. Explain how the six components are measured using the balance.	CO3	Understand	Medium
5	How do you measure the flow turbulence in wind tunnel? Explain. What is meant by flow angularity? How do you measure the same in wind tunnel?	CO3	Understand	Medium
6	Explain the calibration procedures for supersonic wind tunnels in brief.	CO3	Understand	Medium
7	(i) Elaborate on hypersonic shock tunnel. (ii) Explain the working principle of a hypersonic wind tunnel.	CO3	Understand	Medium
8	(i) What are the three fundamental principles used to model low speed	CO3	Understand	Medium

	aerodynamics flow? (ii) What is the importance of wind tunnels in design?			
9	(i) Explain wind tunnel boundary layers. (ii) Methods of smoke formation.	CO3	Understand	Medium
10	(i) Describe the calibration of supersonic tunnel. (ii) Determine the Mach Number in the calibration of a supersonic tunnel.	CO3	Create	High

UNIT – IV

WIND TUNNEL INSTRUMENTATION

PART–A				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	List the merits and demerits of pressure sensitive paints.	CO4	Remember	Low
2	What is meant by PIV?	CO4	Understand	Low
3	What are the advantages of flow visualization methods?	CO4	Understand	Low
4	How is total pressure estimated in the test section of a supersonic wind tunnel?	CO4	Understand	Medium
5	What is the primary objective of tuft flow visualization?	CO4	Understand	Low
6	What is the principle behind optical flow visualization techniques?	CO4	Understand	Low
7	Write the sensors used for steady and unsteady measurements.	CO4	Understand	Low
8	Write a note on calibration of measuring instruments.	CO4	Understand	Low
9	Classify flow visualization.	CO4	Analyze	Low
10	What are the advantages of using Tufts?	CO4	Understand	Low

PART-B				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	Explain the basic principles of Scheleieren method of flow visualization with a neat diagram. Mention the advantages and limitations of this method.	CO4	Understand	Medium
2	Explain the modern three component balance for force and moment measurements in wind tunnel with neat sketches.	CO4	Understand	Medium
3	Write short notes on the following techniques: (i) Smoke technique for flow visualization. (ii) Use of tufts and electrical techniques for flow visualization studies.	CO4	Understand	Medium
4	With aid of schematic diagram explain the construction of compound balance. Element Name and sketch at least three types of flexures and three types of force fastenings techniques.	CO4	Understand	Medium
5	Explain the basic principle of Laser Doppler anemometry. Show that in a direction shift in frequency is directly proportional to the component of velocity of the reference vector.	CO4	Understand	Medium
6	Explain the automated wind tunnel system with the help of a neat block diagram for tunnel wind speed control.	CO4	Understand	Medium

7	(i) Write a short note on auto switching of the wind tunnel. (ii) Derive system formulation of automated wind tunnel system.	CO4	Create	High
8	Write short notes on: (i) Flow transducers and flow imaging. (ii) Spatial and temporal characterization of Transducers.	CO4	Understand	Medium
9	Explain the following: (i) Locating points of separation. (ii) Off - surface visualization.	CO4	Understand	Medium
10	Explain the preparation of an arrangement for setting the speed of a wind tunnel.	CO4	Understand	Medium

UNIT – V

FLOW VISUALIZATION and NON-INTRUSIVE FLOW DIAGNOSTICS

PART–A				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	What are the main sources of error in wall static pressure measurements?	CO5	Understand	Low
2	What is horizontal buoyancy?	CO5	Understand	Low
3	What is the basic principle of Doppler anemometry?	CO5	Understand	Low
4	What are the limitations of dye injection method for flow visualization?	CO5	Understand	Low
5	Name the instruments for unsteady pressure measurements.	CO5	Remember	Low
6	What are the constraints for the model design?	CO5	Understand	Low
7	What is Laser Doppler technique?	CO5	Understand	Low
8	What is tuff grid technique?	CO5	Understand	Low
9	Name the types of pressure transducers.	CO5	Remember	Low
10	What is Monometer?	CO5	Understand	Low

PART–B				
Q. No	**Questions**	**CO Mapping**	**BT Level**	**Complexity**
1	Describe the importance of the flow visualisation techniques of surface flow, oil and tuft.	CO5	Understand	Medium
2	Explain the low-speed wind tunnel design procedure with empirical equations and draw the wind tunnel model.	CO5	Understand	Medium
3	Explain the following non-intrusive flow diagnostics methods in detail: (i) Particle image velocimetry (ii) Laser induced florescence.	CO5	Understand	Medium
4	Explain concept of Laser Doppler Anemometry (LDA). and describe the construction and working of a Three-dimensional LDA system.	CO5	Understand	Medium
5	How are the separation studies carried out using wind tunnels? Explain in detail with suitable sketches.	CO5	Understand	Medium
6	With aid of suitable sketches explain the operation of pressure transducers.	CO5	Understand	Medium
7	(i) Why is flow visualization important in aviation? (ii) What are the advantages of flow visualization methods?	CO5	Understand	Medium
8	(i) What is non-intrusive technique? (ii) What is the basic principle involved in the inferometer method of flow visualization?	CO5	Understand	Medium

9	Explain the procedure involved in the unsteady pressure measurements over an angle an airfoil draw the Cpmean, Cprms profiles over NACA 4412 airfoil at of attack of 15 degrees.	CO5	Understand	Medium
10	Explain the low speed wind tunnel design procedure with empherical equations and draw the wind tunnel model.	CO5	Understand	Medium

THANK YOU

ALL THE BEST