INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**AEROSPACE STRUCTURAL DYNAMICS**				
Course Code	AAE015				
Programme	B.Tech				
Semester	VII	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	3	2
Chief Coordinator	Dr. Y B Sudhir Sastry, Professor				
Course Faculty	Dr. Y B Sudhir Sastry, Professor Mr. T. Mahesh Kumar, Assistant Professor				

I. COURSE OVERVIEW:

The course aim is to teach basic concepts and recent developments related to mechanical vibrations, structural dynamics and vibration control. The course seeks to introduce students to the fundamentals of dynamics by providing an overview on mechanical vibration. Vibrations in machines and structures are typically undesirable as they produce stresses, energy losses and increased bearing loads. They contribute to structural wear and can lead to passenger discomfort in vehicles. This course covers the vibrations of discrete systems and continuous structures and introduces the computational dynamics of linear engineering systems. Learn how to derive equations of motion and design vibration isolation systems. Gain an understanding of the concepts of natural frequencies and mode shapes and their significance. Complete system modeling tasks and formulate equations to measure and ultimately minimize vibrations. The concepts of aero elasticity phenomena, effect of aero elasticity in flight vehicle design.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AHS007	I	Applied physics	4
UG	AME002	II	Engineering Mechanics	4
UG	AAE002	III	Theory of Structures	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Aerospace Structural Dynamics	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✗	Chalk & Talk	✓	Quiz	✓	Assignments	✗	MOOCs
✓	LCD / PPT	✓	Seminars	✗	Mini Project	✓	Videos
✗	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignment
PO 2	**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	2	Seminar
PO 5	**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 the public health and safety, and the cultural, societal, and environmental considerations.	1	Seminars

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	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	1	Assignment
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.	2	Assignment
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	1	Laboratory

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
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.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Demonstrate the knowledge of mathematics, science, and engineering by developing the equations of motion for vibratory systems and solving for the free and forced response.
II	Understand to identify, formulate and solve engineering problems. This will be accomplished by having students model, analyze and modify a vibratory structure order to achieve specified requirements.
III	Introduce to structural vibrations which may affect safety and reliability of engineering systems.
IV	Describe structural dynamic and steady and unsteady aerodynamics aspects of airframe and its components of space structures.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the concept of vibrations, equation of motion, response to harmonic excitation, impulsive excitation, step excitation, periodic excitation (Fourier series), Fourier transform), Laplace transform (Transfer Function).	CLO 1	Apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components or processes, and work professionally in mechanical systems areas.
		CLO 2	Become proficient in the modeling and analysis of one degree of freedom systems - free vibrations, transient and steady-state forced vibrations, viscous and hysteric damping.
		CLO 3	Understanding the response to periodic excitation (Fourier series ,Fourier transform)
		CLO 4	Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.
CO 2	Remember and describe the concept of Eigen value problem, damping effect; Modeling of continuous systems as multi-degree-of-freedom systems, equations of motion of undamped systems in matrix form, unrestrained systems, free and forced vibration	CLO 5	Become proficient in the modeling and analysis of multi-dof systems - Lagrange’s equations, reduction to one-dof systems for proportionally damped systems, modal analysis, vibration absorbers, vibration transmission, Fourier transforms.
		CLO 6	Convert the physical domain to mathematical formulation and development of governing equation based on number of masses in the system.
		CLO 7	Understanding the phenomenon of generalized coordinates and generalized forces, Lagrange‘s equations to derive equations of motion

COs	Course Outcome	CLOs	Course Learning Outcome
	vibration of undamped systems; using modal analysis, forced vibration of viscously damped systems.	CLO 8	Apply the Eigen value problem and describe expansion theorem, unrestrained systems, free vibration of undamped systems; forced vibration of undamped systems
CO 3	Determine and apply the concept of nonlinear vibrations physical properties of nonlinear systems single-degree-of-freedom and multi-degree-of-freedom nonlinear systems. Random vibrations;, single-degree-of-freedom response, response to a white noise	CLO 9	Understand the concepts of nonlinear vibrations, simple examples of nonlinear systems, physical properties of nonlinear systems
		CLO 10	Formulate simple problem solutions of the equation of motion of a single-degree-of-freedom nonlinear system, multi-degree-of-freedom nonlinear systems.
		CLO 11	Understand the concept of random processes, probability distribution and density functions, description of the mean values in terms of the probability density function
		CLO 12	Understand the concept of autocorrelation function, power spectral density function, properties of the power spectral density function, white noise and narrow and large bandwidth
CO 4	Describe about transverse vibration of a string or cable, longitudinal vibration of a bar or rod, torsional vibration of shaft or rod, lateral vibration of beams, the Rayleigh-Ritz method.	CLO 13	Understand the concepts of transverse vibration of a string or cable
		CLO 14	Derive the equations longitudinal vibration of a bar or rod, torsional vibration of shaft or rod,
		CLO 15	Solve the problems for lateral vibration of beams, and the Rayleigh-Ritz method.
CO 5	Understand the concept of Collar's aero elastic triangle, static aero elasticity aero elastic problems at transonic speeds, active flutter suppression. Effect of aero elasticity in flight vehicle design	CLO 16	Understand the concepts of Collar's aeroelastic triangle, static aeroelasticity phenomena
		CLO 17	Understand the concept of dynamic aeroelasticity phenomena
		CLO 18	Calculate the aeroelastic problems at transonic speeds, aeroelastic tailoring, active flutter suppression. Effect of aeroelasticity in flight vehicle design.

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE015.01	CLO 1	Apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components or processes, and work professionally in mechanical systems areas.	PO 1	3
AAE015.02	CLO 2	Become proficient in the modeling and analysis of one degree of freedom systems - free vibrations, transient and steady-state forced vibrations, viscous and hysteric damping.	PO 1	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE015.03	CLO 3	Understanding the response to periodic excitation (Fourier series ,Fourier transform)	PO 1, PO 2	3
AAE015.04	CLO 4	Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	PO 1, PO 2	3
AAE015.05	CLO 5	Become proficient in the modeling and analysis of multi-dof systems - Lagrange's equations, reduction to one-dof systems for proportionally damped systems, modal analysis, vibration absorbers, vibration transmission, Fourier transforms.	PO 1, PO 2	3
AAE015.06	CLO 6	Convert the physical domain to mathematical formulation and development of governing equation based on number of masses in the system.	PO 2	2
AAE015.07	CLO 7	Understanding the phenomenon of generalized coordinates and generalized forces, Lagrange's equations to derive equations of motion.	PO 1, PO 2	3
AAE015.08	CLO 8	Apply the Eigen value problem and describe expansion theorem, unrestrained systems, free vibration of undamped systems; forced vibration of undamped systems.	PO 2, PO 5	2
AAE015.09	CLO 9	Understand the concepts of nonlinear vibrations, simple examples of nonlinear systems, physical properties of nonlinear systems	PO 2, PO 5	2
AAE015.10	CLO 10	Formulate simple problem solutions of the equation of motion of a single-degree-of-freedom nonlinear system, multi-degree-of-freedom nonlinear systems.	PO 2	2
AAE015.11	CLO 11	Understand the concept of random processes, probability distribution and density functions, description of the mean values in terms of the probability density function	PO 1	3
AAE015.12	CLO 12	Understand the concept of autocorrelation function, power spectral density function, properties of the power spectral density function, white noise and narrow and large bandwidth	PO 1	3
AAE015.13	CLO 13	Understand the concepts of transverse vibration of a string or cable	PO 1	3
AAE015.14	CLO 14	Derive the equations longitudinal vibration of a bar or rod, torsional vibration of shaft or rod	PO 2	2
AAE015.15	CLO 15	Solve the problems for lateral vibration of beams, and the Rayleigh-Ritz method.	PO 1, PO 2	3
AAE015.16	CLO 16	Understand the concepts of Collar's aeroelastic triangle, static aeroelasticity phenomena	PO 1, PO 5	2
AAE015.17	CLO 17	Understand the concept of dynamic aeroelasticity phenomena	PO 1, PO 5	2
AAE015.18	CLO 18	Calculate the aeroelastic problems at transonic speeds, aeroelastic tailoring, active flutter suppression. Effect of aeroelasticity in flight vehicle design.	PO 2, PO 5	2

3= High; 2 = Medium; 1 = Low

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

Course Outcomes (COs)	Program Outcomes (POs)			Program Specific Outcomes (PSOs)		
	PO 1	**PO 2**	**PO 5**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	3	2	-	-	2	-
CO 2	3	2	1	1	2	-
CO 3	3	2	1	1	-	1
CO 4	3	2	-	1	-	1
CO 5	3	2	1	-	2	1

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

CLOs	Program Outcomes (POs)												Program Specific Outcomes (PSOs)			
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**	**PSO4**
CLO 1	3															
CLO 2	3															
CLO 3	3	2														
CLO 4	3	2												2		
CLO 5	3	2												2		
CLO 6		2											1			
CLO 7	3	2											1			
CLO 8		2			1											
CLO 9		2			1								1	2		
CLO 10	3	2														
CLO 11	3															
CLO 12	3												1		3	
CLO 13	3															
CLO 14		2														
CLO 15	3	2											1		1	
CLO 16	3				1											
CLO 17	3				1											
CLO 18		2			1									2	1	

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XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO5, PSO1, PSO2, PSO3	SEE Exams	PO1, PO2, PO5,PSO1, PSO2, PSO3	Assignments	PO 1, PSO1, PSO2	Seminars	PO 2, PO 5
Laboratory Practices	PSO3	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

✓	Early Semester Feedback	✓	End Semester OBE Feedback
✗	Assessment of Mini Projects by Experts		

XV. SYLLABUS

Unit-I	**SINGLE-DEGREE-OF-FREEDOM LINEAR SYSTEMS**
Introduction to theory of vibration, equation of motion, free vibration, response to harmonic excitation, response to an impulsive excitation, response to a step excitation, response to periodic excitation (Fourier series), response to a periodic excitation (Fourier transform), Laplace transform (Transfer Function).	
Unit-II	**MULTI-DEGREE-OF-FREEDOM LINEAR SYSTEMS**
Equations of motion, free vibration, the Eigen value problem, response to an external applied load, damping effect; Modeling of continuous systems as multi-degree-of-freedom systems, using Newton’s second law to derive equations of motion, influence coefficients - stiffness influence coefficients, flexibility influence coefficients, inertia influence coefficients; potential and kinetic energy expressions in matrix form, generalized coordinates and generalized forces, Lagrange‘s equations to derive equations of motion, equations of motion of undamped systems in matrix form, eigenvalue problem, solution of the Eigen value problem, expansion theorem, unrestrained systems, free vibration of undamped systems; forced vibration of undamped systems using modal analysis, forced vibration of viscously damped systems.	
Unit-III	**NONLINEAR AND RANDOM VIBRATION**
Introduction to nonlinear vibrations, simple examples of nonlinear systems, physical properties of nonlinear systems, solutions of the equation of motion of a single-degree-of-freedom nonlinear system, multi-degree-of-freedom nonlinear systems. Introduction to random vibrations; classification of random processes, probability distribution and density functions, description of the mean values in terms of the probability density function, properties of the autocorrelation function, power spectral density function, properties of the power spectral density function, white noise and narrow and large bandwidth, single-degree-of-freedom response, response to a white noise.	
Unit-IV	**DYNAMICS OF CONTINUOUS ELASTIC BODIES**
Introduction, transverse vibration of a string or cable, longitudinal vibration of a bar or rod, torsional vibration of shaft or rod, lateral vibration of beams, the Rayleigh-Ritz method.	
Unit-V	**INTRODUCTION TO AERO ELASTICITY**
Collar's aero elastic triangle, static aero elasticity phenomena, dynamic aero elasticity phenomena, aero elastic problems at transonic speeds, aero elastic tailoring, active flutter suppression. Effect of aero elasticity in flight vehicle design	

Text Books:
1. Bismarck-Nasr, M.N., ―Structural Dynamics in Aeronautical Engineering‖, AIAA Education Series, 2nd Edition, 1999. 2. Rao, S.S., ―Mechanical Vibrations‖, Prentice-Hall, 5th Edition, 2011. 3. Thomson, W.T., ―Theory of vibrations with applications‖, CBS Publishers, Delhi, 3rd Edition, 2002.
Reference Books:
1. R.L. Bisplinghoff, H.Ashley, and R.L. Halfmann, ―Aero-elasticity, Addison Wesley Publishing Co., Inc., 2nd Edition, 1996. 2. Leissa, A.W., Vibration of continuous system, The McGraw-Hill Company, 2nd Edition, 2011. 3. Inman, D.J., Vibration Engineering, Prentice Hall Int., Inc., 3rd Edition, 2001.

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1-2	Introduction to theory of vibration	CLO 1	T2 : 1.2-1.13
3-5	Equation of motion, free vibration	CLO 2	T1 : 2.1-2.2
6-7	Response to harmonic excitation, response to an impulsive excitation	CLO 3	T1 : 2.3-2.4, T2:1.10.1
7-8	Response to a step excitation, response to periodic excitation (Fourier series)	CLO 3	T1:1.11.1; T1:2.5-2.6
9-11	Response to a periodic excitation (Fourier transform), Laplace transform (Transfer Function).	CLO 4	T1 : 2.7-2.8
12-13	Equations of motion, free vibration, the Eigen value problem, response to an external applied load	CLO 5	T1:3.1-3.3
15	Damping effect; Modeling of continuous systems as multi-degree-of-freedom systems, using Newton's second law to derive equations of motion	CLO 6	T1:3.4; T2:6.2-6.3
15-16	Influence coefficients - stiffness influence coefficients, flexibility influence coefficients, inertia influence coefficients;	CLO 6, CLO 9	T2: 6.4
17	Potential and kinetic energy expressions in matrix form, generalized coordinates and generalized forces	CLO 7	T2:6.5-6.6
18-19	Lagrange‘s equations to derive equations of motion, equations of motion of undamped systems in matrix form, eigenvalue problem	CLO 7, CLO 8	T2:6.7-6.9
20-22	Solution of the Eigen value problem, expansion theorem, unrestrained systems, free vibration of undamped systems	CLO 7, CLO 8	T2:6.10-6.13
23-25	Forced vibration of undamped systems using modal analysis, forced vibration of viscously damped systems.	CLO 9	T2:6.14-6.15
26-29	Introduction to nonlinear vibrations, simple examples of nonlinear systems, physical properties of nonlinear systems	CLO 10	T1:5.1-5.3 T3:3.3
30-31	solutions of the equation of motion of a single-degree-of-freedom nonlinear system, multi-degree-of-freedom nonlinear systems	CLO 11	T1:5.4-5.5
32-34	Introduction to random vibrations; classification of random processes, probability distribution and density functions, description of the mean values in terms of the probability	CLO 12	T1:6.1-6.4 R3:4.4

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
	density function		
35-36	Properties of the autocorrelation function, power spectral density function, properties of the power spectral density function, white noise and narrow and large bandwidth, single-degree-of-freedom response, response to a white noise	CLO 12	T1:6.5-6.10 R3:5.4 T3:4.3
37-38	Introduction, transverse vibration of a string or cable	CLO 13	T2:8.1-8.2
39-41	longitudinal vibration of a bar or rod	CLO 14	T2:8.3
42-44	torsional vibration of shaft or rod	CLO 14, CLO 15	T2:8.4 R2:5.3
45-46	Lateral vibration of beams, the Rayleigh-Ritz method.	CLO 15	T2:8.5-8.7
47-48	Collar's aero elastic triangle, static aero elasticity phenomena	CLO 16	R1:1.2
49-51	Dynamic aero elasticity phenomena, aero elastic problems at transonic speeds	CLO 17	R1:2.2
51-53	Aero elastic tailoring, active flutter suppression	CLO 18	T1:7.1-7.3 R2:1.3
54-55	Effect of aero elasticity in flight vehicle design	CLO 18	R1:3.4

XVII. GAPS IN THE SYLLABUS-TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed actions	Relevance With POS	Relevance With PSOS
1	Gain information about the vibrations of landing gear, and other aircraft components.	Seminars / Guest Lectures	PO 1	PSO 2
2	Encourage students to perform flatter analysis of aircraft wing.	Projects	PO 5	PSO 2

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