INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

MECHANICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**MECHANICAL VIBRATIONS**			
Course Code	**A70346**			
Course Structure	**Lectures**	**Tutorials**	**Practicals**	**Credits**
	4	**1**	**-**	**4**
Course Coordinator	**Prof. VVSH Prasad, Professor, Department of ME**			
Team of Instructors	**Prof. VVSH Prasad, Professor, Department of ME**			

I. COURSE OVERVIEW

The course aims to teach basic concepts and recent developments related to mechanical vibrations, structural dynamics and vibration control. The Dynamics – Introduction to Mechanical Vibration 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.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	3	5	Physics, Mathematics & Numerical Methods, Engineering Mechanics, Mechanics of Solids, Theory of Machines

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
There shall be 2 midterm examinations. Each midterm examination consists of subjective test. The subjective test is for 20 marks, with duration of 2 hours. Subjective test of each semester shall contain 5 one mark compulsory questions in part-A and part-B contains 5 questions, the student has to answer 3 questions, each carrying 5 marks. 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. 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.	75	100

IV. EVALUATION SCHEME

S.No	Component	Duration	Marks
1	I Mid examination	80 minutes	20
2	I Assignment	--	05
3	II Mid examination	80 minutes	20
4	II Assignment	--	05
5	External examination	3 hours	75

V. COURSE OBJECTIVES

I. Develop an understanding of vibration, natural frequency, and mode shape, damping and forcing and establishing ground resonance parameters for mechanical structures.
II. Analyze vibration problems by constructing and solving the differential equations of single degree of freedom cases.
III. Analyze vibration problems by energy methods and spectrum analysis by Laplace transformation methods, time-frequency plots.
IV. Apply modal analysis and synthesis to two degree of freedom cases and continuous vibration systems.
V. Apply this understanding to vibration design problems to multi dof and critical speeds of rotors.

VI. COURSE OUTCOMES

After completing this course the student must demonstrate the knowledge and ability to:

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.
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.
3. Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.
4. 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.
5. Convert the physical domain to mathematical formulation and development of governing equation based on number of masses in the system.
6. Understanding the phenomenon of damping coefficient applied to viscous structural and coulomb damping in the vibration systems.
7. Understanding the concept of frequency monitoring and measurement systems for a predictable analysis of failure from fatigue loads.
8. Development of two rotor system and drawing the elastic lines and identifying the node points.
9. Understanding the semi definite and degenerating systems with two degrees of freedom system and solutions for the partial differential equations.
10. Development of governing equation for multi degrees of freedom system involving damping and external excitation force.
11. Development of Donkerly’s method for multi degrees of freedom system considering the mass of the system.
12. Concept of influential coefficients applied in multi lode parameters using Rayleigh-Ritz method using energy methods.
13. Introduction of numerical methods for determining fundamental and other modes of frequencies for multi degrees of freedom systems.
14. Application of matrix iteration method for finding out nodal frequencies and understanding the mode shapes.
15. Application of Stoodola’s method and Holzer’s method for determining the torsional vibrations of the mechanical systems.

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	H	Assignments and Tutorials
PO2	**Problem Analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	H	Tutorials
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 the public health and safety, and the cultural, societal, and environmental considerations.	H	Exams
PO4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	S	Mini Projects
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.	H	Assignment
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	N	----
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.	N	----
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	S	----
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	N	----
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.	N	----
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.	H	Mini Projects
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	N	----

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency Assessed by
PSO 1	**Professional Skills:** To produce engineering professional capable of synthesizing and analyzing mechanical systems including allied engineering streams.	H	Lectures, Assignments
PSO 2	**Practical implementation and testing skills:** An ability to adopt and integrate current technologies in the design and manufacturing domain to enhance the employability.	S	Projects
PSO 3	**Successful Career and Entrepreneurship:** To build the nation, by imparting technological inputs and managerial skills to become Technocrats.	H	Guest Lectures

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

IX. SYLLABUS

UNIT – I

SINGLE DEGREE OF FREEDOM SYSTEMS: Undamped and damped free vibrations; forced vibrations coulomb damping; Response to excitation; rotating unbalance and support excitation; vibration isolation and transmissibility, Response to Non Periodic Excitations: Unit impulse, unit step and unit Ramp functions; response to arbitrary excitations, The Convolution Integral; shock spectrum; System response by the Laplace Transformation method.

UNIT – II

TWO DEGREE FREEDOM SYSTEMS: Principal modes- undamped and damped free and forced vibrations; undamped vibration absorbers.

UNIT – III

MULTI DEGREE FREEDOM SYSTEMS: Matrix formulation, stiffness and flexibility influence coefficients; Eigen value problem; normal modes and their properties; Free and forced vibration by Modal analysis; Method of matrix inversion; Torsional vibrations of multi- rotor systems and geared systems; Discrete- Time systems.

Vibration measuring instruments: Vibrometers, velocity meters & accelerometers

UNIT – IV

Frequency Domain Vibration analysis: Overview, machine train monitoring parameters, data base development, Vibration data acquisition, trending analysis, failure node analysis, root cause analysis.

UNIT – V

NUMERICAL METHODS: Raleigh's stodola's, Matrix iteration, Rayleigh- Ritz Method and Holzer's methods

Textbooks:

1. Mechanical Vibrations/Groover/Nem Chand and Bros
2. Elements of Vibration Analysis by Meirovitch, TMH, 2001

Reference books:

1. Mechanical Vibrations/Schaum Series/ McGraw Hill
2. Mechanical Vibrations / SS Rao/ Pearson/ 2009, Ed 4,
3. Mechanical Vibrations/Debabrata Nag/Wiley
4. Vibration problems in Engineering / S.P. Timoshenko.
5. Mechanical Vibrations and sound engineering/ A.G.Ambekar/ PHI
6. Theory and Practice of Mechanical Vibrations/JS Rao & K. Gupta/New Age Intl. Publishers/Revised 2nd Edition

X. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No.	CLO	Unit	Course Learning Outcomes	Topics to be covered	Reference
1-16	1-3	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. Become proficient in the	SINGLE DEGREE OF FREEDOM SYSTEMS: Introduction. Undamped and damped free vibrations forced vibrations coulomb damping Response to excitation; rotating unbalance and support excitation vibration isolation and transmissibility	T1 1.1-1.2 &1.4 R2 1.1-1.2

			modeling and analysis of one degree of freedom systems - free vibrations, transient and steady-state forced vibrations, viscous and hysteric damping. Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	Introduction, Response to Non Periodic Excitations Unit impulse, unit step and unit Ramp functions Response to arbitrary excitations The Convolution Integral; shock spectrum; System response by the Laplace Transformation method.	T1 1.5&1.7 R2 3.1-3.3
17-24	4-6	2	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. Convert the physical domain to mathematical formulation and development of governing equation based on number of masses in the system. Understanding the phenomenon of damping coefficient applied to viscous structural and coulomb damping in the vibration systems.	TWO DEGREE FREEDOM SYSTEMS: Introduction Principal modes Undamped and damped free and forced vibrations. Undamped vibration absorbers	T1 3.1-3.2 R2 3.6
25-34	7-8	3	Understanding the concept of frequency monitoring and measurement systems for a predictable analysis of failure from fatigue loads. Development of two rotor system and drawing the elastic lines and identifying the node points.	MULTI DEGREE FREEDOM SYSTEMS: Matrix formulation Stiffness and flexibility influence coefficients Eigen value problem; normal modes and their properties Torsional vibrations of multi- rotor systems and geared systems; Discrete- Time systems.	T1 4.1-4.5
35-38	9		Understanding the semi definite and degenerating systems with two degrees of freedom system and solutions for the partial differential equations.	Introduction: Vibration measuring instruments. Vibrometers, velocity meters & accelerometers.	T1 6.1-6.3
39-57	10-12	4	Development of governing equation for multi degrees of freedom system involving damping and external excitation force. Development of Donkerly's method for multi degrees of freedom system considering the mass of the system. Concept of influential coefficients applied in multi lode parameters using Rayleigh-Ritz method using energy methods.	Frequency domain vibration analysis: Overview data base development, vibration data acquisition trending analysis failure node analysis signature analysis root cause analysis	T1 7.1-7.5

58-69	13-15	5	Introduction of numerical methods for determining fundamental and other modes of frequencies for multi degrees of freedom systems. Application of matrix iteration method for finding out nodal frequencies and understanding the mode shapes. Application of Stoodola's method and Holzer's method for determining the torsional vibrations of the mechanical systems.	NUMERICAL METHODS: Raleigh's Stoodola's, Matrix iteration Rayleigh-Ritz Method Holzer's methods.	T1 8.1-8.3
Lecture No.	**CLO**	**Unit**	**Course Learning Outcomes**	**Topics to be covered**	
1	1	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.	SINGLE DEGREE OF FREEDOM SYSTEMS: Introduction.	T1 1.1
2-3	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.	Undamped and damped free vibrations;	T1 1.2
4-5	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.	forced vibrations coulomb damping;	T1 1.3
6-7	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.	Response to excitation; rotating unbalance and support excitation;	T1 1.4 R2 1.2
8-9	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.	vibration isolation and transmissibility	T11.5
10	2		Become proficient in the	Introduction, Response to	T1 1.7

			modeling and analysis of one degree of freedom systems - free vibrations, transient and steady-state forced vibrations, viscous and hysteric damping.	Non Periodic Excitations	
11	3		Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	Unit impulse, unit step and unit Ramp functions	R2 3.1
12	3		Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	Response to arbitrary excitations	R2 3.2
13-14	3		Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	The Convolution Integral; shock spectrum;	R2 3.3
15-16	3		Using Laplace transforms and the Convolutional integral formulations to understand shock spectrum and system response for impact loads.	System response by the Laplace Transformation method.	R2 3.3
17	4	2	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.	TWO DEGREE FREEDOM SYSTEMS: Introduction, Principal modes	T1 3.1
18-20	5		Convert the physical domain to mathematical formulation and development of governing equation based on number of masses in the system.	Undamped and damped free and forced vibrations.	T1 3.2
21-24	6		Understanding the phenomenon of damping coefficient applied to viscous structural and coulomb damping in the vibration systems.	undamped vibration absorbers	R2 3.6
25	7	3	Understanding the concept of frequency monitoring and measurement systems for a predictable analysis of failure from fatigue loads.	MULTI DEGREE FREEDOM SYSTEMS: Matrix formulation	T1 4.1
26-27	7		Understanding the concept of frequency monitoring and measurement systems for a predictable analysis of failure from fatigue loads.	Stiffness and flexibility influence coefficients	T1 4.2

28-30	8		Development of two rotor system and drawing the elastic lines and identifying the node points.	Eigen value problem; normal modes and their properties	T1 4.3
31-34	8		Development of two rotor system and drawing the elastic lines and identifying the node points.	Torsional vibrations of multi- rotor systems and geared systems; Discrete-Time systems.	T1 4.4
35	9		Develop relative amplitude for a 1 dof damped excited system.	Introduction: Vibration measuring instruments.	T1 4..5
36-38	9		Formulate & Compare with respect to magnification factor, phase angle vs. frequency ratio to identify vibrometer, velorometer, and accelerometer.	Vibrometers, velocity meters & accelerometers.	T1 4.5 T1 6.1-6.3
39-41	10	4	Development of governing equation for multi degrees of freedom system involving damping and external excitation force.	UNIT 4-Frequency domain vibration analysis: Overview	T1 7.1
42-44	10		Development of governing equation for multi degrees of freedom system involving damping and external excitation force.	data base development, vibration data acquisition	T17.2
45-47	11		Development of Donkerly's method for multi degrees of freedom system considering the mass of the system.	trending analysis	T1 7.3
48-51	11		Development of Donkerly's method for multi degrees of freedom system considering the mass of the system.	failure node analysis	T1 7.4
52-54	12		Concept of influential coefficients applied in multi lode parameters using Rayleigh-Ritz method using energy methods.	signature analysis	T1 7.5
55-57	12		Concept of influential coefficients applied in multi lode parameters using Rayleigh-Ritz method using energy methods.	root cause analysis	T1 7.5
58-59	13	5	Introduction of numerical methods for determining fundamental and other modes of frequencies for multi degrees of freedom systems	NUMERICAL METHODS: Raleigh's Stoodola's,	T1 8.1
60-62	13		Introduction of numerical methods for determining fundamental and other modes of frequencies for multi degrees of freedom systems	Matrix iteration	T1 8.2
64-66	14		Application of matrix iteration method for finding out nodal frequencies and understanding the mode shapes.	Rayleigh- Ritz Method	T1 8.3
67-69	15		Application of Stoodola's method and Holzer's method for determining the torsional vibrations of the mechanical systems.	Holzer's methods.	T1 8.3

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

Course Objectives	Program Outcomes												Program Specific Outcomes		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
I	H				S								S		
II					S						H				S
III	H		S											H	
IV		S									H				S
V													H		
VI				H							S			H	S

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

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

Course Outcomes	Program Outcomes												Program Specific Outcomes		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
1	H				S										S
2		H									S		S		
3		H			S										
4	S										H			H	
5											H				S
6					S										
7		S									H		S		
8					H										
9			H											H	
10		H									S				S
11	H												S		
12					H										
13		H		S										H	
14	H					S							S		
15		H			S										S

N = None **S = Supportive** **H = highly related**

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Prepared by:
Prof. VVSH Prasad, Professor.

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