2023-24

MECHANICAL ENGINEERING

MECHANICAL VIBRATIONS

PREPARED BY
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Techno India NJR Institute of Technology

Course File

6ME4-03: MECHANICAL VIBRATIONS

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Syllabus

3rd Year - VI Semester: B.Tech. : Mechanical Engineering

6ME4-03: MECHANICAL VIBRATIONS

Credit: 3 **Max. Marks: 150(IA:30, ETE:120)**

3L+0T+0P **End Term Exam: 3 Hours**

SN	Contents	Hours
1	Introduction: Objective, scope and outcome of the course.	1
2	Introduction to Sound: Frequency dependent human response to sound, Sound pressure dependent human response, Relationship among sound power, sound intensity and sound pressure level.	2
	Introduction to Noise: Auditory and Non auditory effects of Noise, Major sources of the noise, Industrial noise sources, Industrial noise control strategies.	3
	Introduction to Vibration: Importance and scope of vibrations, terminology and classification, Concept of Degrees of freedom, Harmonic motion, vectorial representation, complex number representation, addition.	3
3	Undamped Single Degree of Freedom System: Derivation of equation of motion for one dimensional longitudinal, transverse and torsional vibrations without damping using Newton's second law, D' Alembert's principle and Principle of conservation of energy, Compound pendulum and centre of percussion.	3
	Damped vibrations of single degree of freedom systems: Viscous damping, under-damped, critically damped and over-damped systems, Logarithmic decrement.	3
	Vibration characteristics of Coulomb damped system and Vibration characteristics of Hysteretic damped systems.	2
3	Forced Vibrations of Single Degree of Freedom Systems: Forced vibration with constant harmonic excitation, Steady state and transient parts, Frequency response curves and phase angle plot, Forced vibration due to excitation of support.	4
	Vibration Isolation and Transmissibility: Force transmissibility, Motion transmissibility, Forced vibration with rotating and reciprocating unbalance, Materials used in vibration isolation.	4
5	System with Two Degrees of Freedom: principle mode of vibration, Mode shapes, Undamped forced vibrations of two degrees of freedom system with harmonic excitation, Vibration Absorber, Undamped dynamic vibration absorber and centrifugal pendulum absorber	5
	Critical Speed of Shaft: Critical speed of a light shaft without damping, critical speed of shaft having multiple discs, secondary critical speed.	3
6	Many Degrees of Freedom Systems (Exact analysis): Equation of Motion, The matrix method, Eigen Values and Eigen Vectors, Method of influence Coefficients and Maxwell's reciprocal theorem. Torsional vibrations of multi rotor system, vibrations of geared system, Generalized coordinates and coordinate coupling Many Degrees of Freedom Systems (approximate methods): Rayleigh's, Dunkerley's, Stodola's and Holzer's methods	5
	Vibrations of continuous systems: Transverse vibration of a string, Longitudinal vibration of a bar, Torsional vibration of a shaft.	3
	TOTAL	**41**

Course Overview:

Vibration is a common phenomenon occurring in a mechanical system. For example, vibration of a rotor due to unbalanced mass, vibration of a vehicle engine at varying speed. The study of a dedicated course is required to understand the fundamental and advance concepts of mechanical vibrations for engineers and designers. This course is of basic level. It introduces fundamentals of vibration, vibration of single Degree of Freedom (DoF) system, 2-DoF and multi-DoF systems, continuous systems such as bars and beams, and whirling of shafts.

Course Outcomes:

CO. NO.	Cognitive Level	Course Outcome
1	Synthesis	Explain the causes and effects of vibration in mechanical systems.
2	Synthesis	Formulate schematic models for physical systems and formulate governing equations of motion.
3	Synthesis	Explain the role of damping, stiffness and inertia in mechanical systems
4	Synthesis	Summarise rotating and reciprocating systems and compute critical speeds.
5	Design	Reorganize and design machine supporting structures, vibration isolators and absorbers.

Prerequisites:

1. Basic knowledge of Strength of Material.
2. Concepts of Engineering mechanics, basic physics and SHM.
3. Concept of linear and higher order differential equation, matrix

Course Outcome Mapping with Program Outcome:

Course Outcome	Program Outcomes (PO's)											
CO. NO.	Domain Specific (PSO)					Domain Independent (PO)						
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	1	-	-	-	-	-	-	-
CO2	3	2	3	2	1	-	-	-	-	-	-	-
CO3	3	3	3	2	2	-	-	-	-	-	-	-
CO4	2	2	2	2	1	-	-	-	-	-	-	-
CO5	2	2	2	2	2	1	-	-	-	-	-	-
1: Slight (Low) , 2: Moderate (Medium), 3: Substantial (High)												

Course Coverage Module Wise:

Lecture No.	Unit	Topic
1	**1**	**INTRODUCTION**
2	**2**	Students will able to know the basic concepts related to Sound: Frequency dependent human response to sound
3	2	Students will able to know the basic concepts related Sound pressure dependent human response, Relationship among sound power, Sound intensity and sound pressure level
4	**2**	**INTRODUCTION TO NOISE:** Students will able to know the basic concepts related Auditory and Non auditory effects of Noise
5	2	Students will able to know the Major sources of the noise, Industrial noise sources, Industrial noise control strategies
6	**2**	**INTRODUCTION TO VIBRATION:** Students will able to know the Importance and scope of vibrations, Terminology and classification, Concept of Degrees of freedom
7	2	Students will able to know the Harmonic motion, vectorial representation, complex number representation, addition
8	**3**	**UNDAMPED SINGLE DEGREE OF FREEDOM SYSTEM:** Students will able to know the equation of motion for one dimensional longitudinal vibration
9	3	Students will able to know the transverse and torsional vibrations without damping using Newton's second law
10	3	Students will able to apply the D' Alembert's principle and Principle of conservation of energy
11	3	Students will able to know the Compound pendulum and center of percussion.
12	**3**	**DAMPED VIBRATIONS OF SINGLE DEGREE OF FREEDOM SYSTEMS:** Students will able to know the Viscous damping, under-damped,
13	3	Students will able to know the critically damped and over-damped systems,

14	3	Students will able to know the Logarithmic decrement.
15	**3**	Students will able to know the Vibration characteristics of Coulomb damped system
16	3	Students will able to know the Vibration characteristics of Hysteretic damped systems.
17	**4**	**FORCED VIBRATIONS OF SINGLE DEGREE OF FREEDOM SYSTEMS:** Students will able to know the Forced vibration with constant harmonic excitation
18	4	Students will able to know the Steady state and transient parts
19	4	Students will able to know the Frequency response curves and phase angle plot
20	4	Students will able to know the Forced vibration due to excitation of support
21	**4**	**VIBRATION ISOLATION AND TRANSMISSIBILITY:** Students will able to know the Force transmissibility concept
22	4	Students will able to know the Motion transmissibility concept
23	4	Students will able to know the forced vibration with rotating and reciprocating unbalance system
24	4	Students will able to know the materials used in vibration isolation.
25	**5**	**SYSTEM WITH TWO DEGREES OF FREEDOM:** Students will able to know the principle mode of vibration, Mode shapes concepts
26	5	Students will able to know the Undamped forced vibrations of two degrees of freedom system with harmonic excitation
27	5	Students will able to know the Undamped forced vibrations of two degrees of freedom system with harmonic excitation
28	5	Students will able to know the Vibration Absorber, Undamped dynamic vibration absorber
29	5	Students will able to know the centrifugal pendulum absorber
30	**5**	**CRITICAL SPEED OF SHAFT:** Students will able to know the Critical speed of a light shaft without damping,
31	5	Students will able to know the Critical speed of shaft having multiple discs
32	5	Students will able to know the Critical speed of shaft having multiple discs, Secondary critical speed.
33	**6**	**MANY DEGREES OF FREEDOM SYSTEMS (EXACT ANALYSIS):** Students will able to know the Equation of Motion, The matrix method,
34	6	Students will able to know the Eigen Values and Eigen Vectors, Method of influence Coefficients
35	6	Students will able to know the Maxwell's reciprocal theorem.
36	6	Students will able to know the Torsional vibrations of multi rotor system, vibrations of geared system,
37	6	Students will able to know the Generalized coordinates and coordinate coupling Many Degrees of Freedom Systems (approximate methods): Rayleigh's Method, Dunkerley's method
38	6	Students will able to know the Stodola's method & Holzer's methods

39	**6**	**VIBRATIONS OF CONTINUOUS SYSTEMS:** Students will able to know the Transverse vibration of a string,
40	6	Students will able to know the Longitudinal vibration of a bar
41	6	Students will able to know the Torsional vibration of a shaft

Text Books

1. Mechanical Vibrations (S. I. Units) by G.K. Grover, published by Nem Chand and Bros.
2. Mehta JS, Kailey AS, "Mechanical Vibrations" published by S Chand.

References

1. Rao S.S., "Mechanical Vibrations", Pearson Education, 2nd Indian Reprint
2. Ambekar A.G., "Mechanical Vibrations and Noise Engineering", Prentice Hall of India Pvt. Ltd.

Assessment Methodology:

1. Conducting vica voce examination on weekly basis.
2. Practical exam in lab where students have to apply their theoretical understanding to perform experiments practically and correlate them analytically. (Once in a week)
3. Assignments one from each unit.
4. Midterm subjective paper where they have to solve basic questions with numerical and derivations from each unit. (Twice during the semester)
5. Final paper at the end of the semester subjective.

Teaching and Learning resources unit-wise:

Unit-1

Introduction to Vibration

Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Unit-2

Undamped Single Degree of Freedom System
Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Unit-3

Damped Single Degree of Freedom System
Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Unit-4

Forced Vibration of Single Degree of Freedom System
Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Vibration Isolation & Transmissibility
Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Unit-5

System with 2 degrees of freedom
systems Video Tutorials:
https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/
Critical speed of

shaft Video Tutorials:

https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Unit-6

Multi degrees of freedom systems (Exact Analysis)

Video Tutorials:

https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Vibration of Continuous systems

Video Tutorials:

https://youtu.be/9r630K5HmJc?list=PLSGws_74K01_pG3R7rgtDtrDZBjcTgPdR

Theory concepts: https://nptel.ac.in/courses/112/103/112103111/

Sample Quiz: https://www.sanfoundry.com/machine-dynamics-questions-answers-vibratory-motion/

Previous Year Question Papers:

6E7014

Roll No. _____ [Total No. of Pages : 4

6E7014

B.Tech. VI Semester (Main & Back) Examination, April/May-2017

Mechanical Engineering

6ME4A Vibration Engineering

Time : 3 Hours **Maximum Marks : 80**

Min. Passing Marks : 26

Instructions to Candidates:

*Attempt any **five questions**, selecting **one question** from **each unit**. All Questions carry **equal** marks. (Schematic diagrams must be shown wherever necessary. Any data you feel missing suitable be assumed and stated clearly.) Units of quantities used/calculated must be stated clearly.*

Unit-I

1. a) Enlist the major noise sources in industrial environment. What control measures can be adopted for noise control at the source? **(8)**

   b) What do you understand by sound pressure dependent human response? Derive the relationship between sound power level and sound intensity level. **(8)**

OR

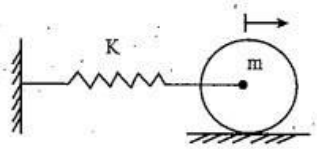
1. a) For the complex numbers $z_1 = (1 + 2i)$ and $z_2 = (3 - 4i)$, find the ratio z_1/z_2 and express the result in the form of $Ae^{i\theta}$. **(8)**

   b) Find the sum of the two harmonic motions $x_1(t) = 5 \cos (3t + 1)$ and $x_2(t) = 10 \cos (3t + 2)$ using trignometric relations. **(8)**

Unit-II

2. a) A spring-mass system k_1, m_1 has a natural frequency 'f_1'. Calculate the value of k_2, another spring which when connected to k_1 in series decreases the frequency by 20%. **(8)**

   b) A circular cylinder of mass 4kg and radius 12cm is connected by a spring of stiffness 6000 N/m as shown in figure. It is free to roll on horizontal rough surface without slipping, determine the natural frequency. **(8)**



2. a) A vibrating system is defined by the following parameters : m = 3kg, k = 100 N/m and c = 3 N-sec/m. Determine **(8)**

i) the damping ratio

ii) the natural frequency of damped vibration

iii) logarithmic decrement

iv) the number of cycles after which the original amplitude is reduced to 20 percent.

b) A body of mass m = 1kg, lies on a dry horizontal plane and is connected by spring to a rigid support. The body is displaced from the unstressed position by an amount equal to 0.25 m with the tension of 50 N in the spring for this new position. How many complete cycles of motion will be performed after being released from this position. How much time it will take to perform this motion if the coefficient of friction is 0.25? **(8)**

Unit-III

3. a) Derive the relation for force transmissibility and draw a neat plot of the force transmissibility ratio with frequency ratio for different values of damping. **(8)**

b) A 70 kg machine is mounted on a springs of stiffness $k = 14 \times 10^5$ N/m with an assumed damping factor of $\zeta = 0.20$. A 2kg piston within the machine has a reciprocating motion with a stroke of 0.08m and a speed of 2700 rpm. Assuming the motion of the piston to be harmonic, calculate the amplitude of vibration of the machine and the vibratory force transmitted to the foundation. **(8)**

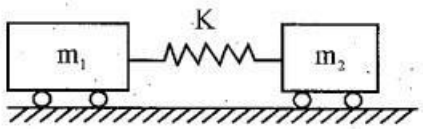
OR

3. a) A 100 kg machine is mounted at the midspan of a 2.0 m long simply supported beam of elastic modulus $E = 200 \times 10^9$ N/m^2 and cross section moment of inertia $I = 2 \times 10^{-6}$ m^4. This system during an experiment was subjected to a harmonic excitation magnitude 2000 N at different excitation frequency. The largest steady-state amplitude recorded during experiment was 2.4 mm. Determine the damping ratio of the system. **(8)**

b) A spring - man - damper system is subjected to a harmonic force. The amplitude is found to be 20 mm at resonance and 10 mm at a frequency 0.75 times the resonant frequency. Find the damping ratio of the system. **(8)**

4. a) With the help of suitable mathematical derivation explain the principle of undamped dynamic vibration absorber. **(8)**

b) Determine the natural frequencies and mode shaper of the system shown in figure. **(8)**



$m_1 = 5$ kg

$m_2 = 10$ kg

$k = 3000$ N/m

Comment on the rigid body mode obtained.

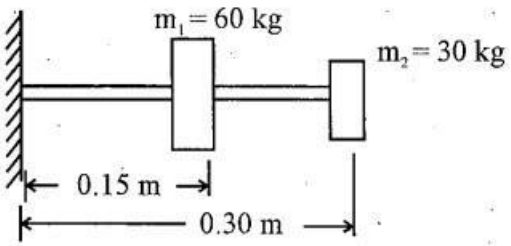
OR

4. a) Derive the mathematical relationship between the deflection of the geometric centre and the eccentricity with other system parameter for a single rotor shaft with damping. **(8)**

b) A rotor has a mass of 10 kg mounted midway on a 24 mm diameter horizontal shaft supported at the ends by two bearings which are 1m apart. The shaft rotates at 2400 rpm. If the centre of mass m of the rotor is 0.12mm away from geometric centre of the rotar due to certain manufacturing defects, find the amplitude of the steady state vibration and dynamic force transmitted to the bearing. Take $E = 200$ GN/m^2. **(8)**

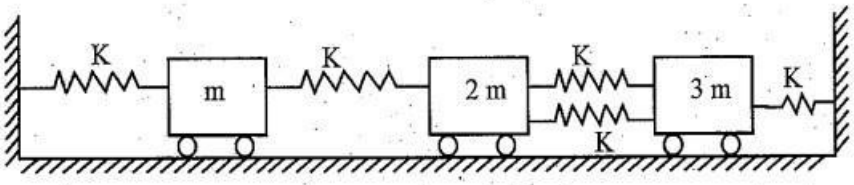
Unit-V

5. a) Find the lowest natural frequency of the system shown in figure using dunkerley's method. **(8)**



Take $E = 2 \times 10^{11}$ N/m^2 and cross section moment of inertia of the beam $I = 4 \times 10^{-7}$ m.

b) Draw the free body diagram of each of the mass shown in the following many degrees of freedom system shown in figure. Derive the governing differential equation of motion using Newton's law of motion. Arrange thus obtained equation in matrix form. **(8)**



OR

5. Derive the governing equation of motion for the torsional vibration of a shaft. Obtain the frequency equation and mode shape for the shaft fixed at one end while free at the other end. **(16)**

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6E7014

6E7014

B. Tech. VI-Sem. (Main & Back) Exam., April/May-2016
Mechanical Engineering
6ME4A Vibration Engineering

Time: 3 Hours **Maximum Marks: 80**

Min. Passing Marks (Main & Back): 26

Instructions to Candidates:-

*Attempt any **five questions,** selecting **one question** from **each unit**. All Questions carry **equal** marks. Schematic diagrams must be shown wherever necessary. Any data you feel missing may suitably be assumed and stated clearly.*

Units of quantities used/ calculated must be stated clearly.

Use of following supporting material is permitted during examination. (Mentioned in form No. 205)

1. NIL 2. NIL

UNIT-I

Q.1 (a) Discuss various methods used in controlling industrial noise. [8]

(b) Explain term loudness. How does it vary with the frequency? How this variation is taken in account in the subjective assessment. [8]

OR

Q.1 (a) What are the auditory and non – auditory effects of noise. [8]

(b) Derive an equation for finding out sound intensity at a distance r from the source of sound of known sound power level. [8]

UNIT-II

Q.2 (a) A 5 kg mass attached to the lower end of a spring, where upper end fixed, vibrates with a natural period of 0.45 sec. Determine the natural period when a 2.5 kg mass is attached to the midpoint of the same spring with upper and lower ends fixed. [8]

(b) A shaft supported freely at the ends has a mass of 100 kg placed 25 cm from one end. Find the frequency of the natural transverse vibration if the length of the shaft is 75 cm, E = 200 GN/M^2 and shaft diameter is 4 cm. [8]

OR

Q.2 (a) What do you understand by under – damped system, over damped system and critically – damped system and its use? Explain. [3+3+4=10]

(b) A vibratory system in a vehicle is to be designed with the following parameters: K = 100 N/m, c = 2N – Sec/m, m = 1 kg

Calculate the decrease of amplitude from its starting value after complete oscillations and (b) the frequency of oscillation. [6]

UNIT-III

Q.3 (a) Derive an expression for amplitude and phase angle of vibrations because of a rotating unbalance. [8]

(b) A vibrating system having mass 1 kg is suspended by a spring stiffness 1000N/m and it is put to harmonic excitation of 10 N. Assuming viscous damping, determine. [8]

(i) The resonant frequency

(ii) The phase angle at resonance

(iii) The amplitude at resonance

(iv) The frequency corresponding to the peak amplitude and Take C = 40 N – Sec/m.

OR

Q.3 (a) An electric motor is supported on a spring and a dashpot. The spring has the stiffness 6400 N/m and the dashpot offers resistance of 500 N at 4.0 m/sec. The unbalanced mass 0.5 kg rotates at 5 cm radius and the total mass of vibratory system is 20 kg. The motor runs at 400 rpm. Determine:

(i) Damping factor

(ii) Amplitude of vibration and phase angle

(iii) Resonant speed and resonant amplitude and

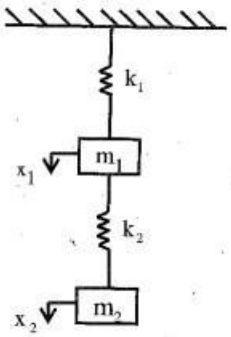
(iv) Forces exerted by the spring and dashpot on the motor. [2+3+3+2=10]

(b) A spring mass damper system is subjected to a harmonic force. The amplitude is found to be 20 mm at resonance and 10 mm at a frequency 0.74 times the resonant frequency. Find the damping ratio of system. [6]

UNIT-IV

Q.4 (a) Explain the principle of undamped dynamic vibration absorber. [8]

(b) Figure shows a vibrating system having two degree of freedom. Determine the tow the two natural frequencies of vibrations and the ratio of amplitudes of the motion of m_1 and m_2 for the two mode of vibration. [8]



OR

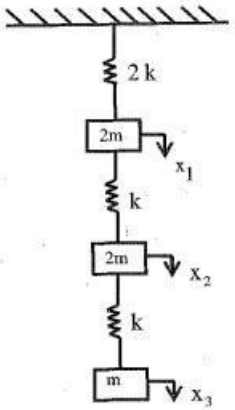
Q.4 (a) Explain principle & working of centrifugal pendulum absorber. [8]

(b) A machine runs at 5000 rpm. Its forcing frequency is very near to its natural frequency. If the nearest frequency of the machine is to at least 20% from the forced frequency, design a suitable vibration absorbed for the system. Assume the mass of the machine as 30 kg. [8]

UNIT-V

Q.5 (a) Write short note on Stodola's Method. [8]

(b) Using matrix method, Determine the natural frequencies of the system shown in figure. [8]



OR

Q.5 Derive governing equation for the torsional vibration of a shaft fixed at both end. Find the frequency equation and mode shapes for the same. [16]
