INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

CIVIL ENGINEERING

QUESTION BANK

Course Name	:	**STRUCTURAL DYNAMICS**
Course Code	:	BSTB12
Class	:	M. Tech (Structural Engineering) – II semester
Department	:	Civil Engineering
Academic Year	:	2018 – 2019
Course Faculty	:	Dr. M. Venu, Professor

COURSE OVERVIEW:

Structural Dynamics is of utmost importance for understanding the analysis and design consideration of structures subjected to dynamic loading. This course introduces the basic concepts of dynamic loading and the response of structures to such loads, and then uses these concepts to illustrate applications in practical structures. It begins with the derivation of the basic equations of motion for an ideal single degree-of-freedom structure using various approaches, and the solution of these equations for different types of loading, with the emphasis on the physical behaviour of the structure to different types of loads to establish simplified methods of analysis. An emphasis on earthquake response of structures is also provided. Further, the development of equations for multi-degree-of-freedom structures is considered, with multi- storied buildings as the example structures, and free and forced vibration response analysis of these multi- storied buildings shall be discussed. An introduction to the dynamics of continuous systems is provided.

COURSE OBJECTIVES:

The course should enable the students to:

I	Analyze and study dynamics response of single degree freedom system using fundamental theory and equation of motion.
II	Analyze and study dynamics response of Multi degree freedom system using fundamental theory and equation of motion.
III	Use the available software for dynamic analysis.

COURSE LEARNING OUTCOMES:

Students, who complete the course, will have demonstrated the ability to do the following:

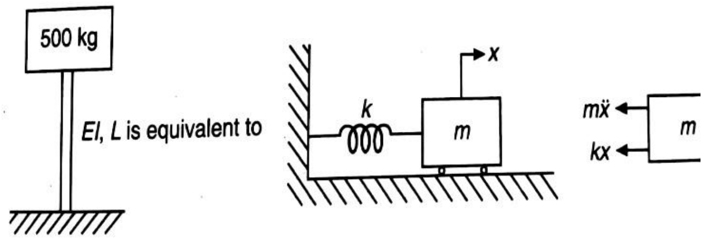
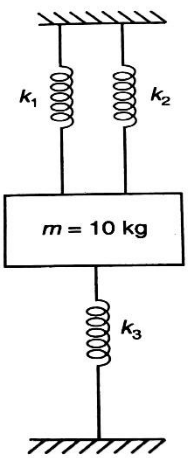
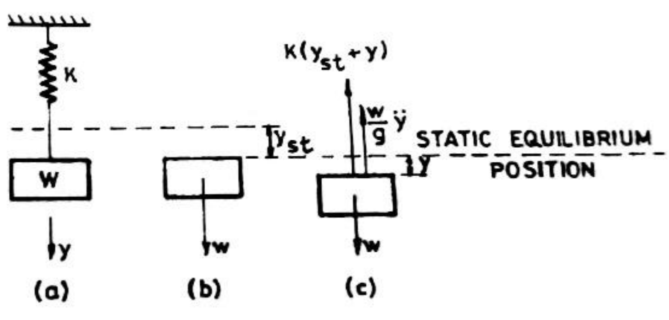
CBSTB12.01	Know the importance of the vibration.
CBSTB12.02	Understand the nature of exciting forces.
CBSTB12.03	Know the mathematical modeling of dynamic systems.
CBSTB12.04	Understand the free and forced vibration without damping.
CBSTB12.05	Understand the free and forced vibration with damping.
CBSTB12.06	Understand the response to harmonic loading.
CBSTB12.07	Understand the response to generaldynamic loading using duhamel’s integral.
CBSTB12.08	Understand the fourier analysis for periodic loading.
CBSTB12.09	Know the space solution forresponse of structure.
CBSTB12.10	Understand the accuracy and stability of structure.
CBSTB12.11	Find the solution to response using new mark method.

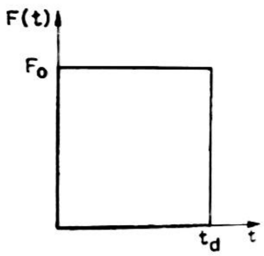
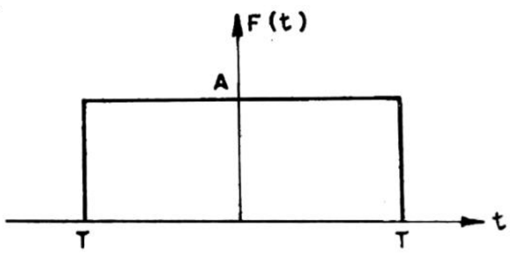
CBSTB12.12	Find the solution to response using wilson method.
CBSTB12.13	Know the space solution for response numerical solution.
CBSTB12.14	Know the space response using direct integration.
CBSTB12.15	Understand the two degree of freedom system.
CBSTB12.16	Understand the multiple degree of freedom system.
CBSTB12.17	Understand the inverse iteration method fordetermination of natural frequencies and mode shapes.
CBSTB12.18	Understand the dynamic response by modal superpositionmethod, direct integration of equation of motion.
CBSTB12.19	Understand the multiple degree of freedom system (distributed mass and load): single span beams.
CBSTB12.20	Understand the free and forcedvibration, generalized single degree of freedom system.
CBSTB12.21	Understand the dynamic effects of wind loading.
CBSTB12.22	Understand the moving loads,vibrations caused by traffic.
CBSTB12.23	Understand the blasting and pile driving, foundations for industrial machinery, base isolation.

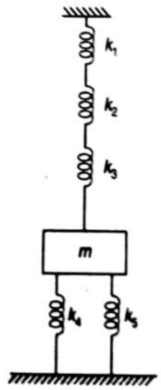
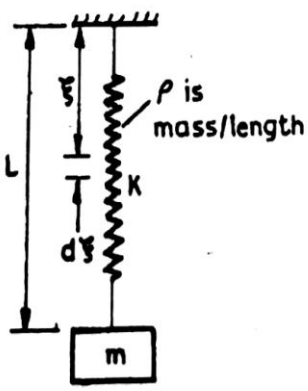
QUESTION BANK

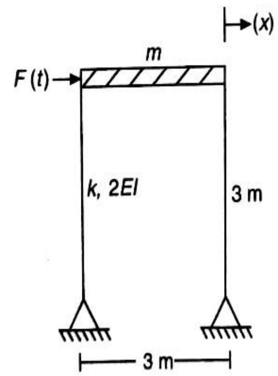
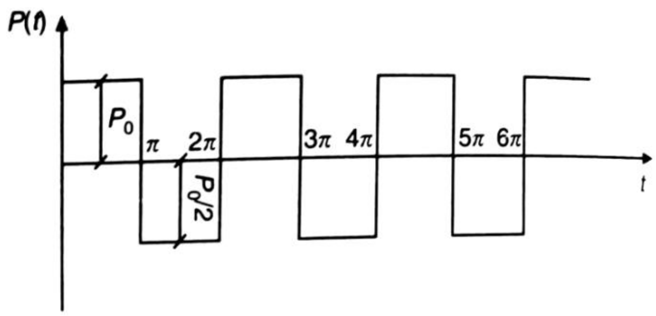
UNIT – I			
INTRODUCTION			
Part - A (Short Answer Questions)			
1	What is meant by periodic motion of vibratory systems? Give two examples of periodic motion.	Remember	CBSTB12.01
2	Define the terms (a) Time Period and (b) Frequency in relation to periodic motion of vibratory systems	Remember	CBSTB12.03
3	Define simple harmonic motion. Give examples of simple harmonic motions	Remember	CBSTB12.01
4	What do we mean by degree of freedom of a vibratory system? Illustrate by a spring mass model.	Remember	CBSTB12.05
5	Sketch themathematical model of a single degree of freedom system	Remember	CBSTB12.04
6	Distinguish between free vibrations and forced vibrations of a vibratory system.	Remember	CBSTB12.02
7	Whatdo you understand by damping in a vibratory system?	Remember	CBSTB12.02
8	What is meant by critical damping?	Remember	CBSTB12.01
9	Distinguish between damping coefficient and damping ratio?	Remember	CBSTB12.02
10	Distinguish between under-damped, critically damping and over-damped system.	Remember	CBSTB12.01
Part - B (Long Answer Questions)			
1	What is dynamic loading? Compare static loading &dynamic loading?	Remember	CBSTB12.01
2	What is meant by degree of freedom and explain types of degrees of freedom with examples?	Remember	CBSTB12.01
3	Explain simple harmonic motion in detail?	Remember	CBSTB12.01
4	A harmonic motion has a time period of 0.2s and an amplitude of 0.4cm.Find maximum velocity and acceleration? Find the same when time period is 0.4s and amplitude is 0.8cm.	Remember	CBSTB12.02
5	Give the causes for dynamic effects with examples?	Remember	CBSTB12.02

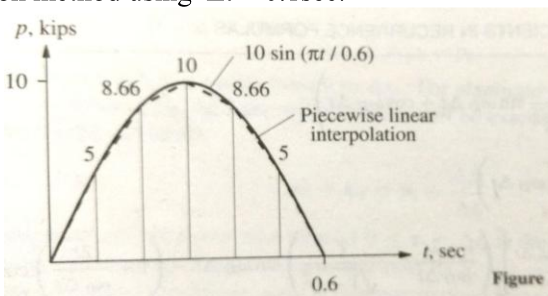
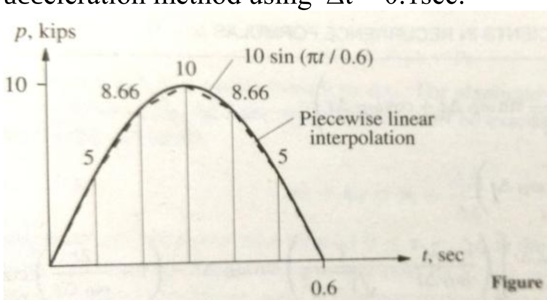
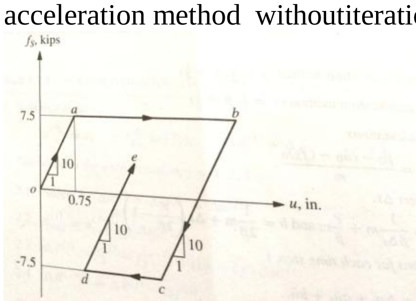
6	Explain the steps involved in vibration analysis?	Remember	CBSTB12.03
7	Explain free vibration of undamped SDOF system?	Remember	CBSTB12.03
8	Derive equivalent stiffness of springs in parallel	Remember	CBSTB12.04
Part - C (Problem Solving and Critical Thinking Questions)			
1	Explain different types of vibrations in detail?	Understand	CBSTB12.01
2	A harmonic motion has a maximum velocity of 6m/s and it has a frequency of 12cps.Determine its amplitude, its period and its maximum acceleration	Understand	CBSTB12.02
3	Give a brief account on mathematical modelling of a single degree of freedom system?	Understand	CBSTB12.02
4	Derive the equation of motion by simple harmonic motion method.	Understand	CBSTB12.03
5	Derive natural frequency by Newton's Second Law of Motion.	Understand	CBSTB12.03
6	Determine natural frequency by Rayleigh's Method	Understand	CBSTB12.04
7	Explain D' Alembert's Principle.	Understand	CBSTB12.04
8	Derive equivalent stiffness of springs in series?	Understand	CBSTB12.05
9	Explain about different sources of excitations?	Understand	CBSTB12.05
10	Write about the classification of vibrations?	Understand	CBSTB12.05
UNIT – II			
SINGLE DEGREE OF FREEDOM SYSTEM			
Part - A (Short Answer Questions)			
1	Give the explanation onvirtual work and its application to Structural Dynamics	Remember	CBSTB12.06
2	State the D' Alembert's principle used in dynamic equilibrium of a vibratory body.	Remember	CBSTB12.06
3	What is meant by damping in vibratory systems? Give the different types of damping models generally used in structural dynamics.	Remember	CBSTB12.06
4	Give the differential equation of motion governing the undamped free vibrations of a single degree of freedom system.	Remember	CBSTB12.07
5	Give the differential equation of motion governing the damped free vibrations of a single degree of freedom system.	Remember	CBSTB12.07
6	Give the differential equation of motion governing the undamped forced vibrations of a single degree of freedom system.	Remember	CBSTB12.08
7	Give the differential equation of motion governing the damped forced vibrations of a single degree of freedom system.	Remember	CBSTB12.09
8	Sketch a typical undamped free vibration response of a single degree of freedom system.	Remember	CBST B12.09
9	Sketch a typical damped free vibration response of a single degree of freedom system.	Remember	CBSTB12.09
10	Explain what is meant by Dynamic Magnification Factor in forced response of a vibratory system.	Remember	CBSTB12.10
Part - B (Long Answer Questions)			
1	Derive the equation for natural frequency and time period?	Apply	CBSTB12.06
2	A vertical cable 3m long has a cross-sectional area of $4 cm^2$ supports a weight of 50kN. What will be the natural period and natural frequency of the system? $E=2.1 \times 10^6$ kg/cm^2.	Apply	CBSTB12.06

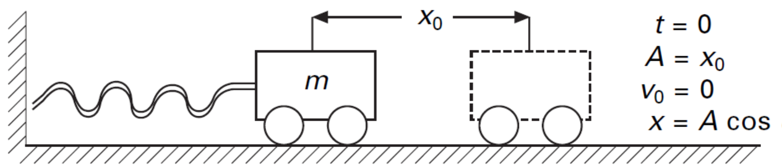
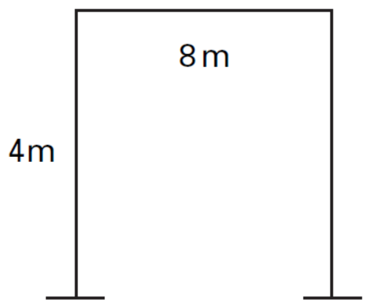
3	A one kg mass is suspended by a spring having a stiffness of 1N/mm. Determine the natural frequency and static deflection of the spring? Find the corresponding if mass=10kg and stiffness=5 N/mm.	Apply	CBSTB12.07
4	A cantilever beam 3m long supports a mass of 500 kg at its upper end .Find the natural period and natural frequency. E=2.1 × 10^6 kg/cm^2 and I=1300 cm^4 	Apply	CBSTB12.07
5	Find the natural frequency of the system as shown in figure. Take k_1= k_2 = 2000 N/m, k_3=3000N/m and m=10 kg. 	Apply	CBSTB12.07
6	A weight W=15N is vertically suspended by a spring of stiffness k=2N/mm. Determine the natural frequency of free vibration of the weight. 	Apply	CBSTB12.08
7	Explain different methods of measurement of damping of forced vibration.	Apply	CBSTB12.09
8	A SDOF spring –mass-damper system is subjected to a harmonic excitation. The amplitude at resonance is found to be 27mm and 12mm at a frequency 0.6 times the resonant frequency. Determine	Apply	CBSTB12.10

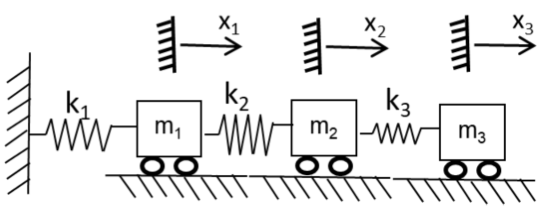
	the damping ratio.		
9	A SDF system is subjected to a suddenly applied load with a limited duration td as shown in figure. Using Duhamel's integral, determine the response of the undamped system. The system starts at rest. 	Apply	CBSTB12.11
10	For a rectangular forcing function of figure given below. Determine the Fourier transform. 	Apply	CBSTB12.11
Part - C (Problem Solving and Critical Thinking Questions)			
1	A mass of 1kg is suspended by a spring having a stiffness of 600 N/m. The mass is displaced downward from its equilibrium position by a distance of 0.01 m. Find (a)Equation of motion of the system (b)Natural frequency of the system (c)The response of the system as a function of time (d)Total energy of the system.	Analyze	CBSTB12.06
2	Consider the system shown in figure if k_1=2000N/m, k_2 = 1500N/m, k_3=3000N/m and k_4=k_5=500N/m, find the mass if the system has a natural frequency of 10Hz.	Analyze	CBSTB12.06

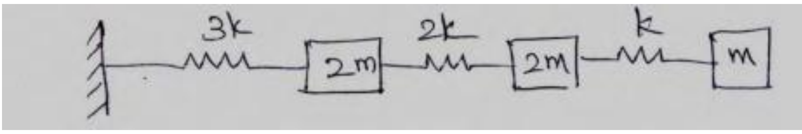
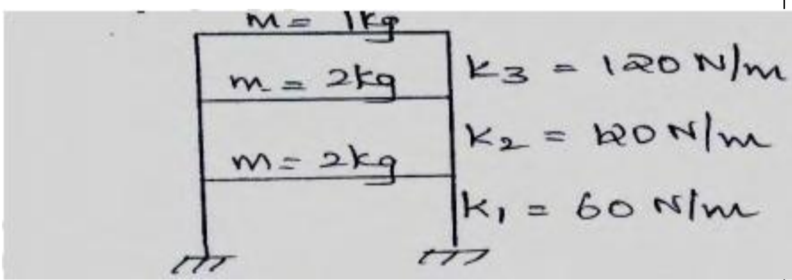
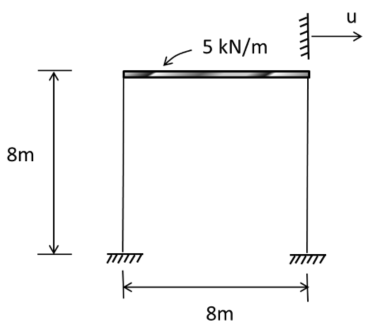
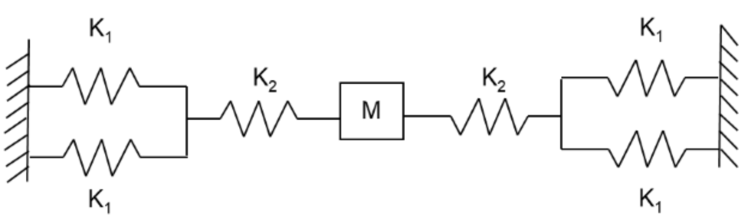
			
3	Calculate the natural angular frequency in sideway for the frame of figure and also the natural period of vibration. If the initial displacement is 25mm and the initial velocity is 25mm/s, what is the amplitude and displacement at t=1s?		CBSTB12.07
4	Determine the natural frequency of an undamped spring mass system by incorporating the effect of mass of the spring. 	Analyze	CBSTB12.07
5	Explain different types of damping (or) Nature of damping?	Understand	CBSTB12.07
6	Explain different methods of measurement of damping of free vibration?	Understand	CBSTB12.08
7	A vibrating system consists of a mass 5kg, spring of stiffness 120N/m and a damper with a damping coefficient of 5N-s/m. Determine: (a) the damping factor,(b)natural frequency of damped vibration,(c)logarithmic decrement,(d)the ratio of two successive amplitudes, and (e) the number of cycles after which the initial amplitude is reduced to 25%.	Analyze	CBSTB12.09
8	Aframe is subjected to an exciting force F(t) =200 sin 20t as shown in figure. Assuming 6% of critical damping, determine: (a) Steady state response of vibration and (b) The maximum dynamic stress in the columns.	Analyze	CBSTB12.09

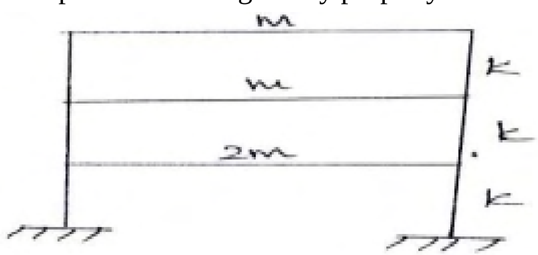
			
9	Derive an expression for the response of an SDOF system for the given loading function. 	Analyze	CBSTB12.10
10	What is response to dynamic loading by Duhamel's integral method.	Understand	CBSTB12.10
	UNIT – III		
	NUMERICAL SOLUTION		
	Part - A (Short Answer Questions)		
1	Write the equation of motion of flexural beamsubjected to free vibration.	Remember	CBSTB12.12
2	Differentiate between flexural and axial vibrationofbars.	Remember	CBSTB12.12
3	Can you have a beamwith both endsfree in flexural vibration mode?Justify.	Remember	CBSTB12.13
4	Listouttheforces acting on beamelement.	Remember	CBSTB12.13
5	Write the general solution for flexural beam.	Remember	CBSTB12.14
6	Evaluatethenaturalfrequencyandmodeshapesforsimplysupporteda tboth ends.	Remember	CBSTB12.14
7	Write the equation of motion ofuniformbeamsubjected to forced vibration.	Remember	CBSTB12.14
8	Write the natural frequency and modeshapes for simply supported at one end.	Remember	CBSTB12.13
9	Discuss aboutthe natural frequencyand mode shapes for both ends free.	Remember	CBSTB12.14
10	Listthe naturalfrequency and modeshapes for both ends fixed.	Remember	CBSTB12.15
	Part - B (Long Answer Questions)		
1	An SDF system has the following properties: m= 0.2533 kip- sec^2 /in., k =10 kips/in.,T_n=1sec (w_n=6.283 rad/sec),and ζ =	Apply	CBSTB12.12

	0.05.Determine the response u(t) of this systemtop(t) defined by the half cycle sine pulse force shown in figure by the average acceleration method using $\Delta t = 0.1$sec.  		
2	An SDF system has the following properties: m= 0.33 kip- sec2 /in., k =10 kips/in.,Tn =1sec (w_n =6.283 rad/sec),and ζ = 0.04.Determine the response u(t) of this systemtop (t) defined by the half cycle sine pulse force shown in figure .1 by the linear acceleration method using $\Delta t = 0.1$sec.  	Apply	CBSTB12.12
3	An SDF system has the following properties: m= 0.2533 kip- sec^2 /in., k =10 kips/in.,T_n =1sec (w_n =6.283 rad/sec),and ζ = 0.05,the restoring force deformation relation iselastoplastic with yield deformation u_y=0.75in.shown in figure.2.Determine the response u(t) of this system(starting from rest) to p(t) defined by the half cycle sine pulse force shown in figure 1 ,by using the average acceleration method withoutiteration ,using $\Delta t = 0.1$sec.  	Apply	CBSTB12.13
4	A mass of 400 g shown in Fig. 2.7 is connected to a light spring whose forceconstant is 5 kN/m. It is free to oscillate on a horizontal frictionless track. Ifthe mass is displaced 10 cm from equilibrium and released from rest, find (a)period of motion, (b) maximum speed of the mass, (c) maximum accelerationof the mass, and (d) equations for displacement, speed and acceleration asfunction of time.	Apply	CBSTB12.14

			
5	A single one storey reinforced concrete (RC) building idealized as a masslessframe is shown in Fig. 2.14 supporting a dead load of 50 kN at the roof level.The frame is 8m wide and 4m high. Each column and beam is 250mmsquare. Assume Young's modulus of concrete as 30 × 106kN/m2 determinethe natural frequency and period of the system. Assume stiffness of anequivalent SDOF system is $k = 96EI/7h3$. 	Understand	CBSTB12.15
Part - C (Problem Solving and Critical Thinking Questions)			
1	Explain the method of estimating the damping of a system from logarithmic decrement derived from the damped vibration response.	Apply	CBSTB12.13
2	An SDOF system consists of a mass of 20 kg, and a spring of stiffness 2200 kN/m anddashpotwithadampingcoefficientof60 Ns/m andissubjected toaforceof F=200 sin5t.Finditssteadystate responseandpeakamplitude.	Apply	CBSTB12.14
3	ASDOFsystemwithamassof50kgandstiffness20N/mmwithdamping 150Ns/mis initially at rest. If theinitial velocity is 100mm/s, (i) Determinethe expression for subsequent displacement. (ii)Find its displacement and velocity at T= 1.5sec.	Apply	CBSTB12.15
4	Estimate the damping in a single degree of freedom system that is excited by a harmonic force. The peak displacement amplitude at resonance was measured equal to 3 cm and equal to 0.2 cm at one-tenth of the natural frequency of the system.	Apply	CBSTB12.16
5	Determine the damping in a system in which during a vibration test under a harmonic force it was observed that at a frequency 10% higher than the resonant frequency, the displacement amplitude was exactly one-half of the resonant amplitude.	Apply	CBSTB12.17
UNIT – IV			
MULTIPLE DEGREE OF FREEDOM SYSTEM (LUMPEDPARAMETER)			
Part - A (Short Answer Questions)			
1	Draw a mathematical model for dynamic analysis of a 4 storey building frame.	Remember	CBSTB12.19

2	Draw the mathematicalmodel ofa 3DOFsystem including damping.	Remember	CBSTB12.19
3	Give lumped mass matrix for a 3 DOF system?	Remember	CBSTB12.20
4	Statethe orthogonalityproperties of dynamic stiffness matrix.	Remember	CBSTB12.20
5	Give stiffness matrix for a 3 DOF system?	Remember	CBSTB12.20
6	What are eigen values and eigen vectors in a dynamic analysis?	Remember	CBSTB12.21
7	Write the equation of motion of an undamped MDOF system with freevibration for a 3 DoF system.	Remember	CBSTB12.21
8	Write the equation of motion of un-damped MDOF system with forced vibration for a 3 DoF system.	Remember	CBSTB12.21
9	Explain what is meant by natural frequencies and mode shapes.	Remember	CBSTB12.21
10	What are the differentmethods toanalyzeforced vibration ofMDOF system?	Remember	CBSTB12.21
Part - B (Long Answer Questions)			
1	(i) Explain how mathematical modelling can be done for a multi-degree freedomsystem. (ii) Derive the governing differential equation and undamped free vibration solution for a three storey shear building frame modelled as oscillators.	Understand	CBSTB12.19
2	Evaluate the natural frequencies and modes of vibration of a two degree of freedom spring – mass oscillators, with equal masses of 10 kg and equal spring stiffness of 100 N/m.	Understand	CBSTB12.19
3	Consider three masses of values m_1 = 10 kg, m_2 = 20 kg and m_3 = 30 kg and three spring of constants k_1 = 100 N/m, k_2 = 120 N/m and k_3 = 90 N/m are connected in series as shown in the figure. Find the mass and stiffness matrices for this system. Find the natural frequencies of the system. 	Understand	CBSTB12.19
4	Evaluatetheeigenvaluesandeigenvectorsforasimplependulumwiththree masses each of 10 kg. Neglect weight of the connectors.	Understand	CBSTB12.19
5	Evaluate the natural frequencies and modes of vibration of a two degree of freedom spring – mass oscillators, with equal masses of 12 kg and equal spring stiffness of 80 N/m.	Understand	CBSTB12.20
Part - C (Problem Solving and Critical Thinking Questions)			
1	The Stiffness and mass matrices of a vibrating system is given below. Determineits fundamental frequency and Mode shapes. $[m] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1.5 & 0 \\ 0 & 0 & 2 \end{bmatrix}$ $[k] = \begin{bmatrix} 600 & -600 & [illegible] \\ -600 & 1800 & -1[illegible] \\ 0 & -1200 & [illegible] \end{bmatrix}$	Apply	CBSTB12.19

2	Evaluate the natural frequencies and the mode shapes for the system shown below:  	Apply	CBSTB12.19
3	Analyse the natural frequencies and the mode shapes for the shear building as shown below:  	Apply	CBSTB12.20
4	Calculate the natural frequency in the horizontal mode of vibration for the frame shown below, where the horizontal member is considered rigid. The cross-section of the columns is 200 X 200 mm^2. The Young's modulus for the material of the members is E = 180 GPa.  	Apply	CBSTB12.20
5	What is equivalent stiffness and the natural frequency for the system illustrated in Figure below?  	Apply	CBSTB12.21
UNIT – V			
MULTIPLE DEGREE OF FREEDOM SYSTEM & SPECIAL TOPICSIN STRUCTURAL DYNAMICS			
Part - A (Short Answer Questions)			
1	What is meant by periodic motion of vibratory systems? Give two examples of periodic motion.	Remember	CBSTB12.21

2	Define the terms (a) Time Period and (b) Frequency in relation to periodic motion of vibratory systems	Remember	CBSTB12.20
3	Define simple harmonic motion. Give examples of simple harmonic motions	Remember	CBSTB12.19
4	What do we mean by degree of freedom of a vibratory system? Illustrate by a spring mass model.	Remember	CBSTB12.21
5	Sketch themathematical model of a single degree of freedom system	Remember	CBSTB12.20
6	Distinguish between free vibrations and forced vibrations of a vibratory system.	Remember	CBSTB12.21
7	Whatdo you understand by damping in a vibratory system?	Remember	CBSTB12.19
8	What is meant by critical damping?	Remember	CBSTB12.20
9	Distinguish between damping coefficient and damping ratio?	Remember	CBSTB12.22
10	Distinguish between under-damped, critically damping and over-damped system.	Remember	CBSTB12.21
Part - B (Long Answer Questions			
1	(a) Calculate the natural frequencies for the given frame. (b) Also prove the orthogonality property of mode shapes.  	Understand	CBSTB12.22
2	A harmonic motion has an amplitude of 0.05 m and a frequency of 25 Hz. Find the time period, maximum velocity and maximum acceleration. Also find the average and rms values of displacement, velocity and acceleration.	Understand	CBSTB12.21
3	A body having a mass of 15kg is suspended from a spring which deflects 12mm under the weight of the mass. Determine the frequency of free vibrationand also the viscous damping force needed to make the motion periodic ora speed of 1mm/s.When dampened to this extent, a disturbing force having a maximumvalue of 100N and vibrating at 6Hz is made to act on the body. Determinethe amplitude of ultimate motion.	Understand	CBSTB12.20
4	A single cylinder vertical diesel engine has a mass of 400kg and is mountedon a steel chassis frame. The static deflection owing to the weight of thechassis is 2.4mm. The reciprocating mass of the engine is 18kg and thestroke of the engine is 160 mm. A dashpot with a damping coefficient of2N/mm/s is also used to dampen the vibration. In the steady state of vibration,determine (a) the amplitude of the vibration if the driving shaft rotates at 500rpm and (b) the speed of the driving shaft when the resonance occurs.	Understand	CBSTB12.21
5	A sensitive instrument with weight 500N is to be installed at a locationwhere vertical acceleration is 0.1*g* and at frequency = 10Hz. Thisinstrumentis mounted on a rubber pad of stiffness	Understand	CBSTB12.23

	12800 N/m and damping such thatthe damping factor is 0.1. (a) What acceleration is transmitted to the instrument? (b) If the instrument can tolerate only an acceleration of 0.005 suggest a solution assuming that the same rubber pad is used.		

Prepared By: Dr. M. Venu, Professor

HEAD
DEPARTMENT OF CIVIL ENGINEERING