Mechanical Engineering

Model Question Papers

For Undergraduate Program

The model question papers are suggestive blueprints. The primary aim of these question papers is to bring clarity about the process of connecting questions to performance indicators and hence to course outcomes. Further, these question papers demonstrate how bloom's taxonomy can be used to understand the quality of question papers and their effectiveness in assessing higher order abilities. The structure of question papers, number of questions, choices given, time given for examination etc., can vary based on the practices of the University or college.

Table of Contents

Course Name: Introduction to Finite Element Methods

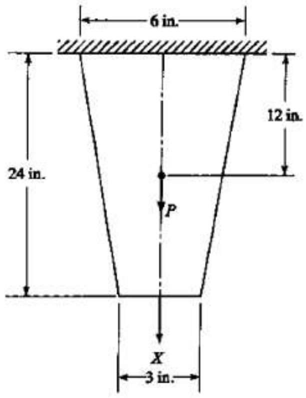
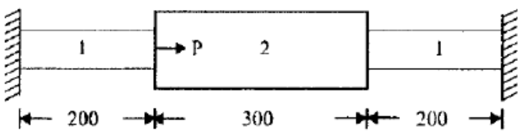
Course Outcomes (CO):

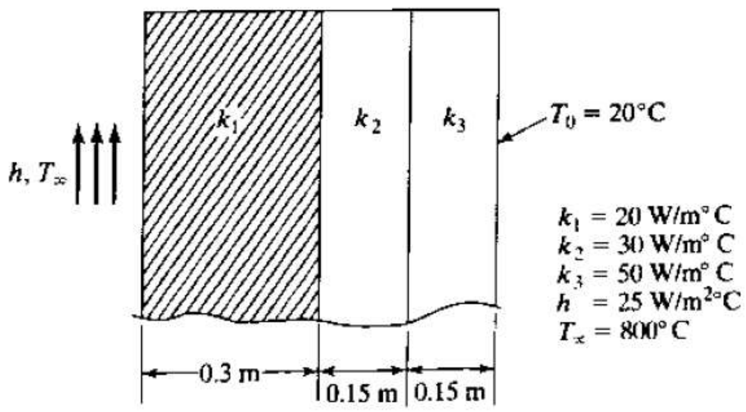
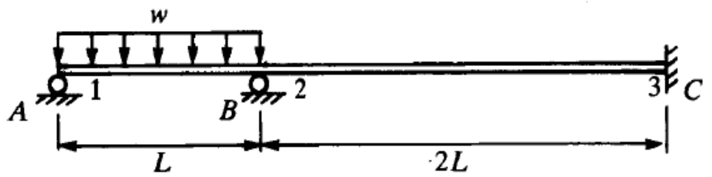
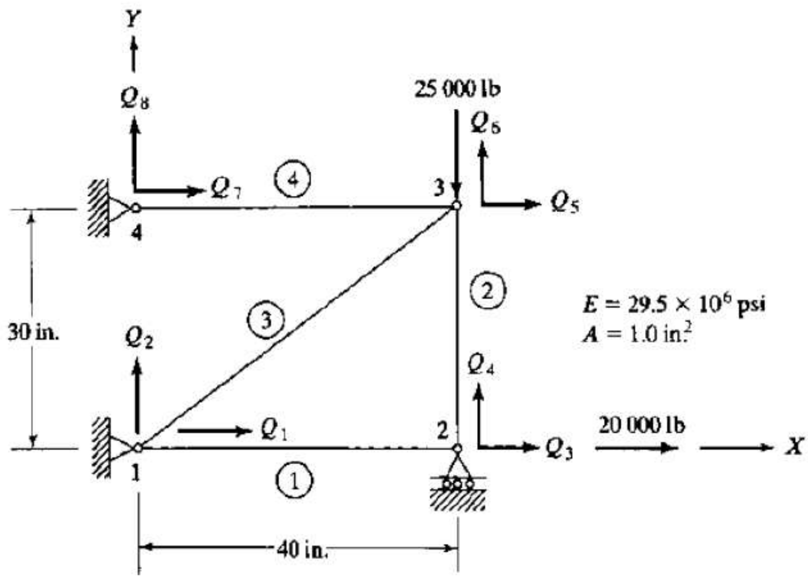
At the end of the course the student should be able to:

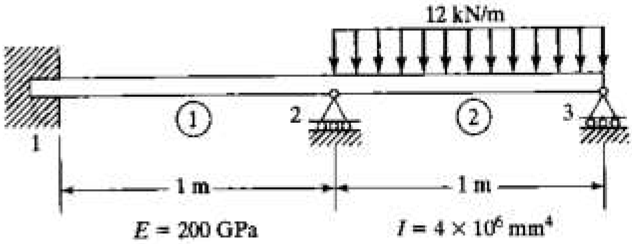
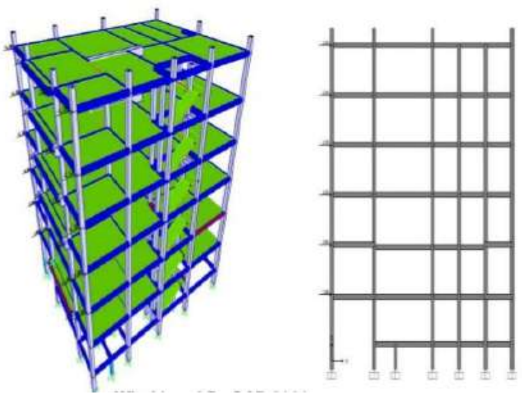
1. Analyze bars and beams using variational principles and weighted residual techniques.
2. Establish shape functions for various elements to arrive at an elemental stiffness matrices and load vectors to obtain global equilibrium equation.
3. Idealize the problem based on various methodologies for performing finite element analysis.
4. Solve analytically the real time field problems related to Static structural, Non-linear, Linear buckling, Dynamic and Thermal analysis.
5. Perform analytical calculations pertaining to Drop/Impact test, Fatigue analysis and Composite structures.
6. Discuss the various experimental methodologies related to Non Destructive testing and draft the report.

Model Question Paper
Total Duration (H:M):3:00
Course : Introduction to Finite Element Methods
Maximum Marks :100

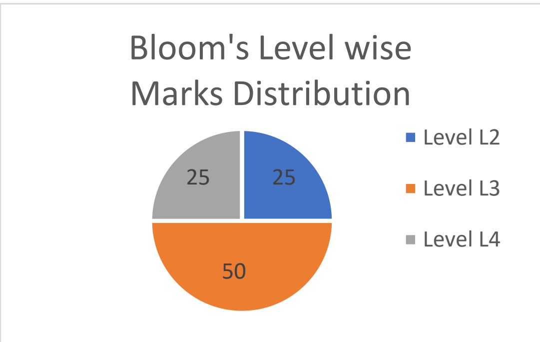
Q.No	Questions	Marks	CO	BL	PI
1a)	Differentiate between FEM, FDM, FVM and BEM. Explain which method is suited for analysis of polymer composite crack propagation along with software tool and justify.	10	CO1	L2	1.4.1
1b)	Using Rayleigh-Ritz method determine the expressions for deflection in a simply supported beam subjected to uniformly distributed load over entire span. Also calculate the percentage of error when RR method values are compared with analytical values.	10	CO1	L3	1.4.1
2a)	Consider a thin (steel) plate as shown in figure 2a. The plate has a uniform thickness t=1in, Youngs modulus E = $30x10^6$psi, and weight density $0.2836lb/in^3$. In addition to its self-weight, the plate is subjected to a point load p = 100lb at its midpoint. a) Model the plate with two finite element points b) Write down the element stiffness matrices and element body force vectors. c) Assemble the structural stiffness matrix K and global load factor F. d) Using the elimination approach, solve for the global displacement vector Q. e) Evaluate the stresses in each element.	10	CO 2	L3	2.3.1

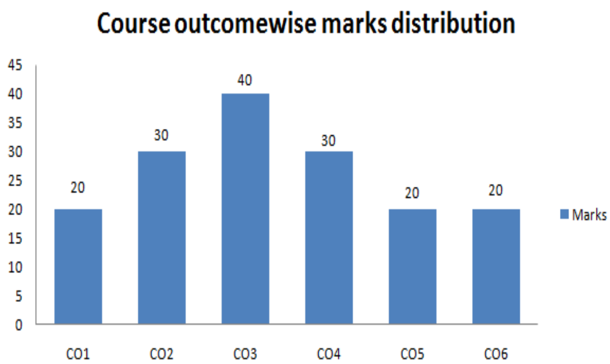
Q.No	Questions	Marks	CO	BL	PI
	 Fig.2a				
2b)	Explain Different types of elements in FEM. Explain H type and P type method with the help of suitable example.	10	CO3	L2	2.4.1
3a)	Using Galerkin's method, establish an expression of the maximum deflection for a cantilever beam having length L, moment of inertia I and young's modulus E, subjected to point load P at the end. Also calculate the percentage of error when Galerkin's method values are compared with analytical values.	10	CO2	L2	2.4.3
3b)	Explain different mesh quality parameters. Discuss any five of them.	10	CO3	L2	2.4.1
UNIT-II					
4a)	For a given problem how a FEA engineer has to decide the following i) Element size ii) Element Type iii) Type of analysis to carry out iv) Linear or Non linear analysis v) How results are compared with real time scenario?	10	CO4	L3	2.4.1
4b)	An axial load $P=200x10^3N$ is applied on a bar as shown in Fig. 4b. Using the penalty approach for handling boundary conditions, determine nodal displacements, stress in each material and reaction forces.  1 - A_1 = 2400 mm^2; E_1 = 70 × 10^9 N/m^2 2 - A_2 – 600 mm2; E_2 – 200 × 10^9 N/m^2 Fig. 4b	10	CO3	L3	2.4.1
5a)	A composite wall consists of three materials, as shown in Fig 5a. The outer temperature is T_o=20°C. Convection heat transfer takes place on the inner surface of the wall with T_∞=800°C and h=25 $W/m^2°C$. Determine the temperature distribution in the wall.	10	CO4	L3	2.4.1

Q.No	Questions	Marks	CO	BL	PI
	 Fig.5a				
5b)	The two span beam structure of Fig.5b is free to rotate at supports A and B and is fixed at joint C. Compute the rotations at supports A and B and the reactions at all supports. Construct Shear Force and Bending Moment Diagrams.  Fig. 5b	10	CO2	L3	2.4.3
6a)	Consider the four bar truss shown in Figure 6a. It is given that modulus of elasticity E= 29.5×10^6 psi and cross-sectional areas A = 1in.^{2}. for all elements. Complete the following: a) Determine the element stiffness matrix for each element. b) Assemble the structural stiffness matrix K for the entire truss. 	10	CO3	L3	2.4.1

Q.No	Questions	Marks	CO	BL	PI
	Fig. 6a				
6b)	For the beam shown in figure 6b, determine the support reactions and stresses in each element. Take E=200 GPa, I=4x10^6 mm^4.  Fig. 6b	10	CO4	L3	2.4.1
UNIT- III					
7a)	Identify the boundary condition and type of analysis need to be carried out for multi storey building for cyclone hit condition as shown in figure 7a and justify your answer with suitable assumptions.  Fig.7a	10	CO5	L4	2.2.3
7b)	Idealize and express the methodology of solving the problem by FEA approach. Consider a person of 100 kg sitting on the bicycle as shown in figure 7b. Justify the answer with suitable assumptions.  Fig.7b	10	CO5	L4	2.2.2

Q.No	Questions	Marks	CO	BL	PI
8a.	The following figure 8a. shows a LCD TV which need to be analyzed for drop test. The average fall height of the LCD TV is 4 feet. Idealize and solve the problem with suitable assumptions.  Fig 8a	10	CO6	L4	2.4.3
8b.	Illustrate different types of analysis that can be possible with a FEA tool and elaborate the process of solving with suitable assumption on material and boundary conditions. The component is as shown in fig 8b.  Fig 8b	10	CO6	L4	2.4.1





BL – Bloom's Taxonomy Levels (1- Remembering, 2- Understanding, 3 – Applying, 4 – Analysing, 5 – Evaluating, 6 - Creating)
CO – Course Outcomes PO – Program Outcomes; PI Code – Performance Indicator Code

Course Name: Design of Thermal Systems

Course Outcomes (CO):

1. Select suitable heat exchanger, based on the heat transfer process, geometry and construction for a given application.
2. Design shell and tube heat exchanger for a given process requirement.
3. Develop mathematical models of the thermal systems like heat exchangers, condensers and evaporators.
4. Analyse design problems on piping system.
5. Develop mathematical statement of optimization for a given thermal system.
6. Optimize thermal systems using Lagrange multipliers method of optimization.
7. Analyse thermal systems using dynamic programming method.

Model Question Paper
Total Duration (H:M):3:00
Course: Design of Thermal Systems
Maximum Marks: 100

ii) Use of Heat transfer data Handbook is permitted.

Note: *i) Answer any two full questions for Unit-1, any two full questions from Unit-II and any one full question from Unit-III*

Q. No.	Questions	Marks	CO	BL	PI
	Unit-I				
1 a	Name the specific heat exchanger construction type that may be used in each of the following application and justify your selection. a. Milk pasteurizing b. Power condenser c. Automotive radiator d. Marine oil cooler e. Air cooled condenser	10	CO1	L3	1.3.1
b	A two shell pass and two tube pass shell & tube heat exchanger is used to heat process fluid (water) from 30°C to 80°C. The mass flow rate of the process fluid is 8000kg/hr and that of the service fluid is 6000kg/hr, which is available at a temperature of 200°C. The overall heat transfer coefficient is 1500W/ m^2K. Find out the outlet temperature of service fluid, and the area required for the heat transfer. After a long time of operation of the heat exchanger, it is found that the outlet temperature of the	10	CO2	L3	1.4.1

	process fluid is only 70°C. Find the fouling resistance developed during this period. Cp of the service fluid = 2.8kJ/Kg K Cp of the process fluid =4.2kJ/Kg K				
2. a	What are the different kinds of spiral plate heat exchangers and what are their limitations?	10	CO1	L2	1.3.1
b.	A counter flow shell and tube heat exchanger is used to cool engine oil flowing through the tube at 0.25kg/s, the specific heat of oil is 2.2kJ/kg K. This oil is cooled by the water, which flows at 0.3kg/s. The oil enters at 560K and leaves at 340K. The cooling water enters at 298K. Find the length of the tube if the heat transfer coefficient from oil to tube surface is 2340W/m^2K, and from tube surface to water is 6215W/m^2K. The mean diameter of the tube is 18mm.	10	CO2	L3	1.4.1
3.a	A process industry uses a shell & tube heat exchanger, the shell specifications are as follows, Length of shell: L_s= 4.5 m Shell diameter ; D_s= 500mm Outside diameter of tube: D_o = 24.5 mm Tube pitch (square) : Pi =32.5 mm Baffle spacing: L_B =132 mm The fluid has the following specifications , Mass flow rate m_i = 5.2kg/s Density ρ = 820 kg/m^3 Specific heat capacity Cp = 2.24 kJ/kg K Dynamic viscosity μ = 0.384 X 10^{-3} Ns/m^2 Thermal conductivity k = 0.125 W/ mK. By Kern's method, find shell side heat transfer coefficient and pressure drop.	10	CO2	L3	1.4.1
b.	A shell & tube heat exchanger has steel pipes of 32mm outer diameter and 26mm inner diameter. Ethylene glycol flows in tubes having a heat transfer coefficient of 1680W/m^2K and a fouling resistance of 0.00065 m^2K/W. Water flows on shell side having a heat transfer coefficient of 3215W/m^2K, and a fouling resistance of 0.0003 m^2K/W. The thermal conductivity of tube is 68 W/ m K. Find the overall heat transfer coefficient of the heat exchanger.	10	CO2	L3	1.4.1
	Unit-II				
4 a.	Between two stages of air compression, the air is to be cooled from 95°C to 10°C. The facility to perform this cooling, shown in Fig Q4 (a), first cools the air in a precooler and then in a refrigeration unit. Water passes through the condenser of the refrigeration unit, then into the precooler, and finally to a cooling tower, where heat is rejected to the atmosphere. The flow rate of compressed air is 1.2 kg/s, and the specific heat is 1.0 kJ/(kg K). The flow rate of water is 2.3 kg/s, and	10	CO5	L4	2.1.2

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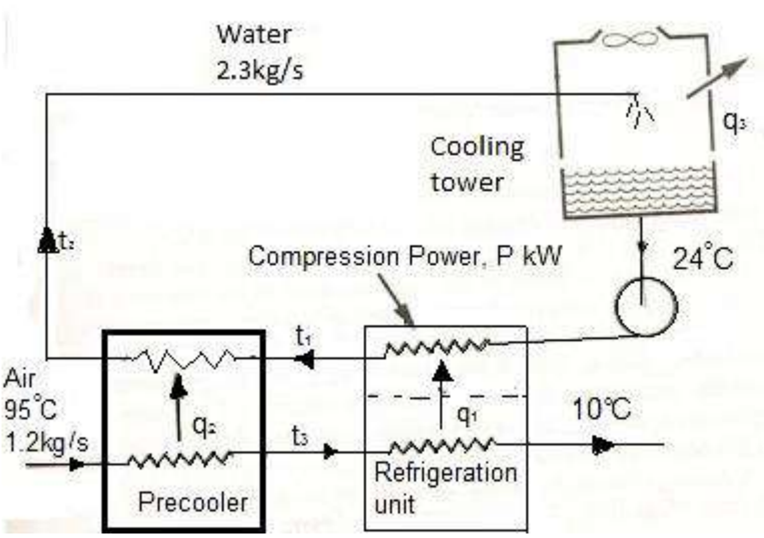
<td>its specific heat is 4.19 kJ/(kg K). The water leaves the cooling tower at a temperature 24°C. The system is to be designed for minimum first cost, where this first cost comprises the cost of the refrigeration unit, precooler, and cooling tower, designated x_1, x_2 and x_3 respectively, in dollars. The expressions for these costs are
Refrigeration unit: $x_1 = 48q_1$
Precooler: $x_2 = 50q_2/(t_3-t_1)$
where the equation is applicable when $t_3 > t_1$
Cooling tower: $x_3 = 25q_3$
where the q's are rates of heat transfer in kilowatts, as designated in figure. The compression power P kW required by the refrigeration unit is $0.25q_1$, and both q1 and the compression power must be absorbed by the condenser cooling water passing through the refrigeration unit.
Develop (a) the objective function and (b) the constraint equations for optimization to provide minimum first cost


Fig. Q4(a): Air cooling system</td>
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<td>b.</td>
<td>Oil at 20°C (ρ =888kg/m^3 and μ =0.800 kg/ms) is flowing steadily through a 0.05 m diameter 40 m long pipe. The pressure at the pipe inlet and outlet are measured to be 745 and 97 kPa, respectively. Determine the flow rate of oil through the pipe assuming the pipe is (a) horizontal, (b) inclined 15° upward, (c) inclined 15° downward. Also verify that the flow through the pipe is laminar.</td>
<td>10</td>
<td>CO4</td>
<td>L3</td>
<td>1.4.1</td>
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<td>5 a.</td>
<td>A counter flow heat exchanger cools 5 kg/s of oil, C_p=2.4 kJ/kg K, with water that has a flow rate of 7.5 kg/s. The specific heat of water is 4.19 kJ/kg K. Under the original operating conditions the oil is cooled from 75°C to 40°C when water enters at 25°C. To what temperature will the oil</td>
<td>10</td>
<td>CO3</td>
<td>L3</td>
<td>1.4.1</td>
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<tr><td></td><td>be cooled if it enters at 65°C and there is no change in the entering water temperature, the flow rates of either fluid or the heat transfer coefficients?</td><td></td><td></td><td></td><td></td></tr>
<tr><td>b</td><td>A water pump is used to pump from one large reservoir to another large reservoir that is at a higher elevation. The free surfaces of both reservoirs are exposed to atmospheric pressure, as sketched in Fig. 5(b). The dimensions and minor loss coefficients are provided in the figure. The pump's performance is approximated by the expression $H_{available} = H_o - aV^2$, where shutoff head H_o=24.4 m of water column, coefficient α =0.0678 m/Lpm^2, available pump head $H_{available}$ is in units of meters of water column, and capacity V is in units of liter per minute. Estimate the capacity delivered by the pump.

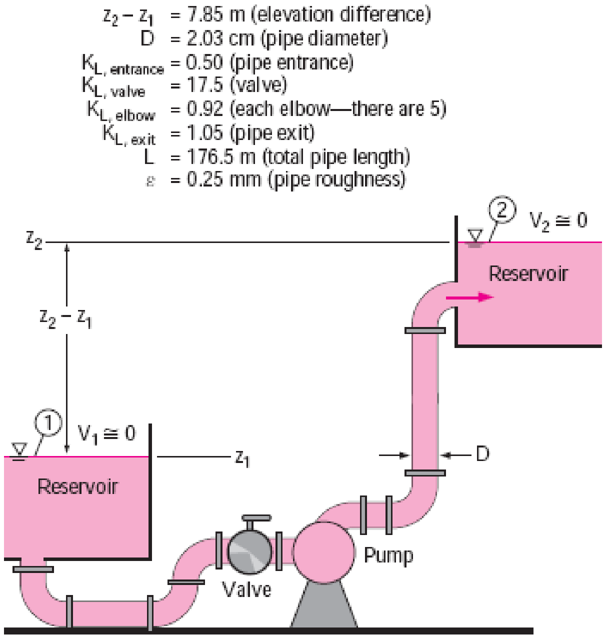


Fig. Q5(b): Pumping System</td><td>10</td><td>CO4</td><td>L3</td><td>1.4.1</td></tr>
<tr><td>6 a</td><td>The performance data for a centrifugal water pump are shown in Table Q6(a) for water at 20°C (Lpm = Litre per minute). (a) For each row of data, calculate the pump efficiency (percent). Show all units and unit conversions for full credit. (b) Estimate the volume flow rate (Lpm) and net head (m) at the BEP of the pump.

Table Q6(a): Pump performance
<table><tr><th>V, LPM</th><th>H, m</th><th>Bp, W</th></tr><tr><td>0.0</td><td>47.5</td><td>133</td></tr><tr><td>6.0</td><td>46.2</td><td>142</td></tr><tr><td>12.0</td><td>42.5</td><td>153</td></tr></table></td><td>10</td><td>CO4</td><td>L3</td><td>1.4.1</td></tr>
</table>

	18.0 36.2 164 24.0 26.2 172 30.0 15.0 174 36.0 0.0 174			
b	A double pipe heat exchanger serves as an oil cooler with oil flowing in one direction through the inner tube and cooling water in the opposite direction through the annulus. The oil flow rate is 0.63 kg/s, oil has a specific heat of 1.68 kJ/kg K, the water flow rate is 0.5 kg/s and its specific heat is 4.19 kJ/kg K. In a test of the prototype, oil entering at 78°C was cooled to 54°C when the entering water temperature was 30°C. The possibility of increasing the area of heat exchanger by increasing the length of the double pipe is to be considered. If the flow rates, fluid properties and entering temperatures remain unchanged, what will be the expected outlet temperature of the oil be if the area is increased by 20 percent?	10	CO3	L3	1.4.1
	Unit-III				
7	A solar collector and storage tank is to be optimized to achieve minimum first cost. During the day the temperature of water in the storage vessel is elevated from 25°C (the minimum useful temperature) to t_{max}. The collector receives 260 W/m^2 of solar energy; but there is heat loss from the collector to the ambient air by convection. The convective heat transfer coefficient is 2 W/m^{2}K, and the average temperature difference during the 10 hour day is (25+t_{max}) / 2 minus the ambient temperature of 10°C. The energy above the minimum useful temperature of 25°C that is to be stored in the vessel during the day is 200,000 kJ. The density of water is 1000 kg/m^3, and its specific heat is 4.19 kJ/kg K. The cost of the solar collector is 20A units, where A is the area in m^2 and the cost of the storage vessel is 101.5V, where V is the volume in cubic meters. (a) Using A and V as the variables, set up the objective function and constraint to optimize the first cost. (b) Develop the Lagrange multiplier equations and verify that they are satisfied by V=1.2m^3 and A=29.2m^2	20	CO6	L4	3.3.1

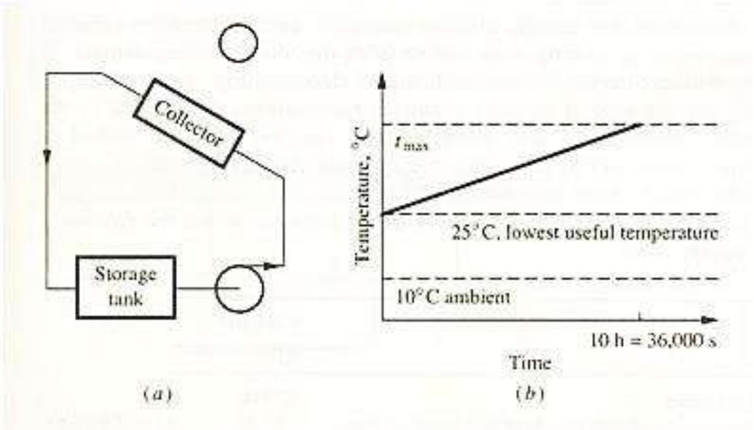


Fig Q7: Solar water heating system

8 The total pressure drop from point 1 to point 5 in the multi-branch duct system shown in Fig. Q8 below is to be 500 Pa. Table Q8, presents the costs for various duct sizes in each of the sections as a function of the pressure drop in the section. Use dynamic programming to determine the pressure drop in each section that results in the minimum total cost of the system.

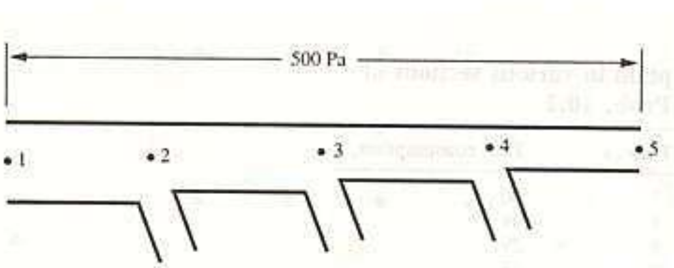
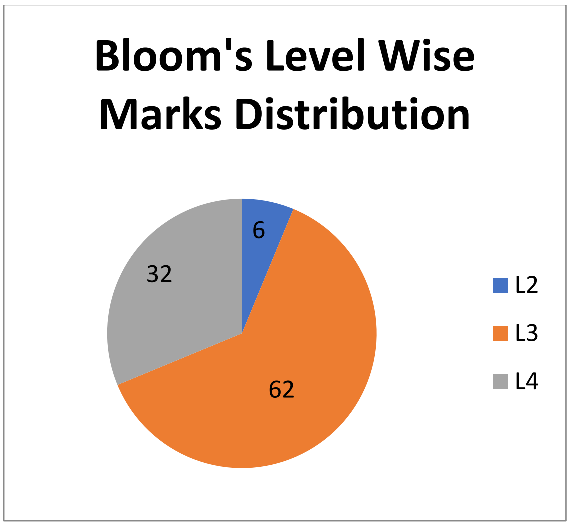


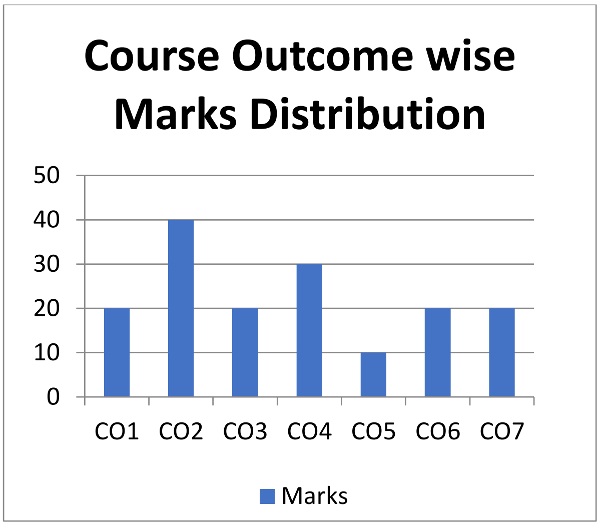
Fig.Q8 : Duct system

Table Q8 : Pressure drop and costs of sections of duct

Section	Pressure drop, Pa	Cost, $
1-2	100	222
	150	205
	200	193
2-3	100	180
	150	166
	200	157
3-4	100	135
	150	125
	200	117
4-5	100	93
	150	86
	200	81

20 CO7 L4 3.3.1





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Course Name: Manufacturing Processes

Course Outcomes (CO):

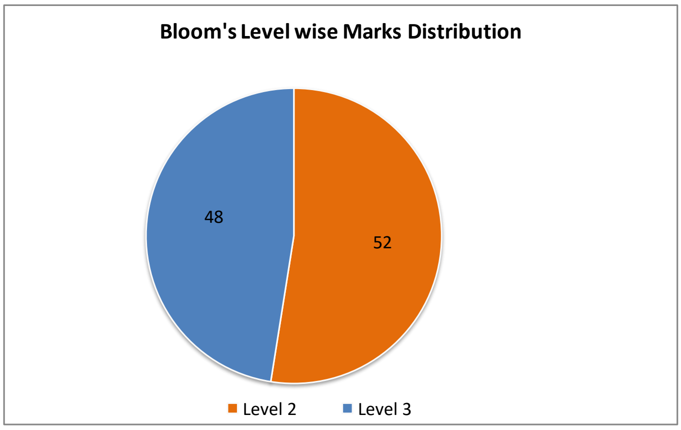
1. Classify manufacturing processes & enumerate the process steps involved in a sand casting process and their applications.
2. Recommend a suitable moulding /casting method (sand/special) & a melting furnace to cast given auto components.
3. Enumerate cleaning/fettling operations and discuss various types of casting defects, possible causes for their occurrence, detection methods and suggest remedies.
4. Suggest a suitable welding process (arc welding, ultrasonic welding, electron beam welding, laser beam welding etc) for a given precision welding job.
5. Illustrate the fundamental principles of metal cutting processes and specify suitable machine tools (traditional/CNC) and develop process plan/part programming for producing given component.
6. Recommend a suitable forming process for a given component.
7. Recommend a suitable non- traditional/micro-machining/high speed machining method for a stated application.

Model Question Paper
Total Duration (H:M):3:00
Course: Manufacturing Processes
Maximum Marks: 100

Q.No	Questions	Marks	CO	BL	PI
1a	Manufacturing processes are classified as, i) Processing operations and ii) Assembly operations Mention sub-classifications under these two categories with suitable examples.	6	CO1	L2	1.4.1
1b	A broken railway track needs welding on-site. Recommend a suitable process & outline its working principle.	6	CO4	L3	1.3.1
1c	Differentiate between Brazing, Soldering and Welding with the following aspects, i) Temperature ii) Type of material to be joined iii) Surface finish and iv) Strength	8	CO4	L2	1.3.1
2a	Discuss the criteria for selection of manufacturing processes.	6	CO1	L2	1.4.1
2b	A precision foundry needs to produce IC engine pistons. Suggest suitable process and explain the procedure with neat sketch.	6	CO2	L3	1.3.1
2c	Explain the post processes of casting, fettling-cleaning and finishing of castings.	8	CO3	L2	1.3.1
3a	Enumerate the steps involved in sand casting.	6	CO2	L2	1.3.1

Q.No	Questions	Marks	CO	BL	PI
3b	A pattern shop has received order to make a wooden pattern for making sand castings. Discuss various pattern allowances to be considered by him to produce the required pattern.	6	CO2	L3	1.3.1
3c	With neat sketch, discuss the working principle of investment casting process and list the advantages & limitations of it.	8	CO2	L2	1.3.1
4a	Draw Merchant's force diagram. State the assumptions made in the development of such a diagram.	6	CO5	L2	2.3.2
4b	Interpret the program syntax. N10 G28 U0 W0; N20 T0101; N30 G00 X35 Z2; N40 G00 X30 M03 S1500; N50 G01 Z64 M08 F0.1;	6	CO5	L3	1.4.1
4c	A drilling operation is performed on a steel part using a 10mm diameter twist drill with point angle 118^0. The hole is blind hole with depth of 60mm. Cutting speed=15m/min and feed =0.20mm/rev. Determine, i) Cutting time of the operation ii) Material removal rate	8	CO5	L3	2.1.3
5a	Considering the suitable example, explain open and closed loop control system.	6	CO5	L2	1.4.1
5b	Enumerate the advantages and disadvantages of CNC machines.	6	CO5	L2	1.4.1
5c	In orthogonal cutting operation on a material with the shear yield strength of 250N/mm², the following data is observed. Rake angle= 20^0 Uncut chip thickness= 0.3mm Width of chip= 1.5mm Chip thickness ratio= 0.4 Friction angle= 40^0 Determine, i) The shear angle ii) The cutting force component iii) The resultant force on the tool	8	CO5	L3	2.1.3
6a	When do you recommend the climb milling and up milling? Explain the same with diagram.	6	CO5	L3	1.4.1
6b	A typical tool signature of single point cutting tool is 0-7-6-8-15-16-0.8. Interpret this and show with neat sketch of the tool.	6	CO5	L2	2.3.1
6c	A peripheral milling operation is performed on the top surface of a rectangular work part which is 200mm long and 40mm wide. The milling cutter, which is 90mm in diameter and has 13 teeth, overhangs the width of the part on both sides. Cutting speed = 70m/min, chip load = 0.2mm/tooth depth of cut = 6mm	8	CO5	L3	1.4.1

Q.No	Questions	Marks	CO	BL	PI
	Determine: i) The actual machining time to make one pass ii) The material removal rate.				
7a	Differentiate between bulk deformation & sheet metal working.	6	CO6	L2	2.1.2
7b	Explain the advantages of thread rolling over thread cutting (machining).	6	CO6	L2	1.3.1
7c	Determine the minimum force capacity press to perform the blanking operation on 1.5mm thick mild steel sheet with shear strength of 360N/mm². The blanking profile is rectangle with 50×100mm dimensions. Also find the total force required if there were two 13mm diameter holes to be pierced simultaneously in the previous station along with blanking.	8	CO6	L3	1.3.1
8a	Explain in what cases do you prefer non-traditional machining process suitable.	6	CO7	L3	1.4.1
8b	Explain electric discharge machining process principle with neat sketch and state its applications.	6	CO7	L2	1.4.1
8c	Additive manufacturing is the key component for the "future of manufacturing". Explain your understanding of the statement and outline two process that are in use today.	8	CO7	L3	2.1.3



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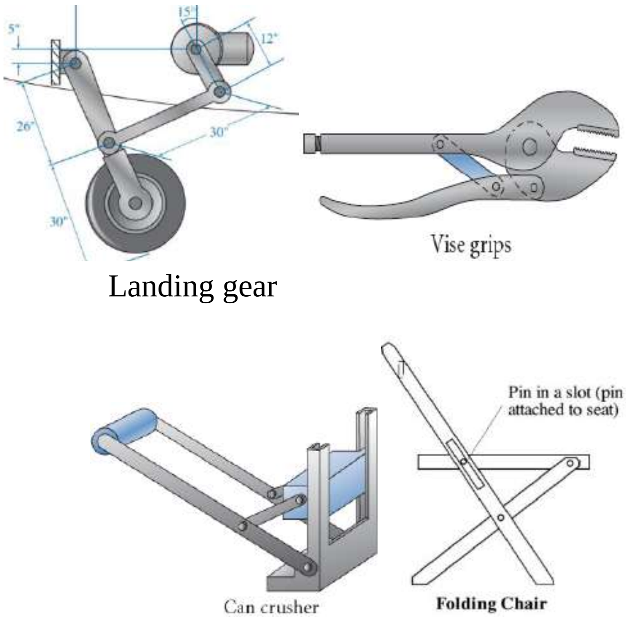
Course Name: Machines & Mechanisms

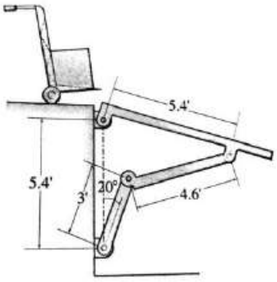
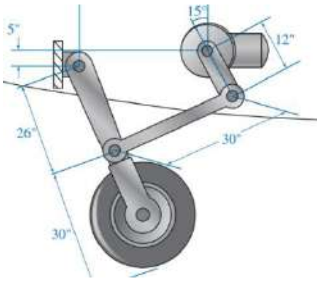
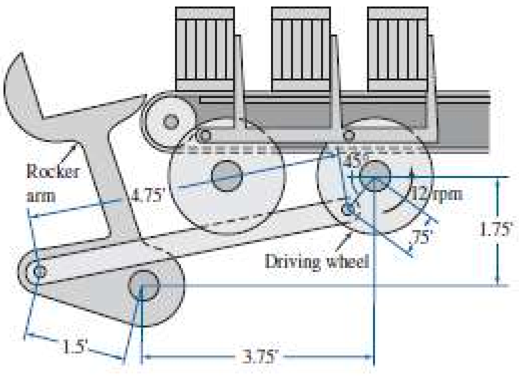
Course Outcomes (CO):

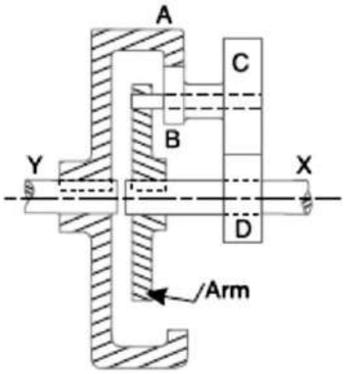
1. Analyze the given machine/mechanism for their type and mobility
2. Determine the velocity and acceleration of links in the mechanism using graphical and analytical methods.
3. Carry out the static and dynamic force analysis for a given mechanism.
4. Formulate the equations for kinematic and dynamic analysis of gear and gear trains for a given gear arrangement.
5. Analyze the dynamic forces and couples on rotating and reciprocating components of machines to compute the magnitude and direction of balancing mass.
6. Develop a cam profile for a given follower motions.
7. Ascertain the gyroscopic and centrifugal couple fora given application

Model Question Paper
Total Duration (H:M): 3:00
Course: Machines & Mechanisms (15EMEC204)
Maximum Mark: 100

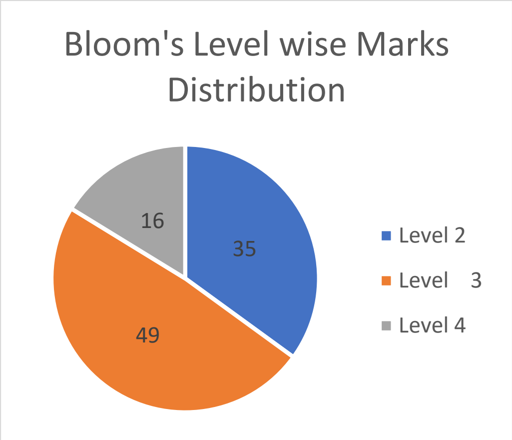
Note: *i) Answer any two full questions for Unit-1, any two full questions from Unit-II and any one full question from Unit-III*

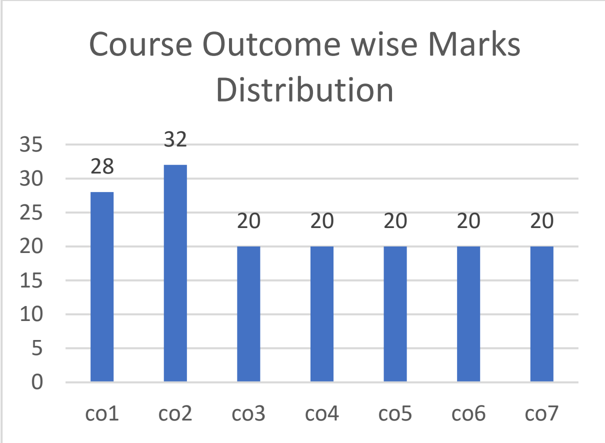
Q.No.	Questions	Marks	CO	BL	PI
	Unit 1				
1a)	Draw the kinematic diagram for the mechanisms shown in the Fig.Q1a (i to iv). Compute the mobility.  Fig.Q1a (i to iv)	10	CO1	L3	2.1.2

1b)	For the mechanisms shown in the Fig. Q1b i) and ii), locate all the instantaneous centers.   Fig Q1b.i) Self-locking brace Fig Q1b.ii) Landing gear	10	CO2	L2	2.1.3
2a)	Three links in a kinematic chain move relatively to each other. Prove that they have three instantaneous centers and lie in a straight line	8	CO2	L2	1.3.1
2b)	The gearbox shaft and propeller shaft of an automobile are connected by a universal joint. Obtain the expression for ratio of output shaft speed to input shaft speed. analyze the conditions when propeller shaft will have i) maximum speed ii) minimum speed and iii) both shafts have equal speeds.	12	CO1	L3	1.3.1
3a)	Describe with neat sketch the mechanism used in the automobile steering system and obtain the expression for condition of correct steering.	6	CO1	L2	1.3.1
3b)	The mechanism shown in the Fig. Q3b) is used to feed cartons to a labeling machine and, at the same time, to prevent the stored cartons from moving down. At full speed, the driveshaft rotates clockwise with an angular velocity of 200 rpm. At the instant shown, determine the acceleration of the rocker arm that rotates and lowers the parts.  Fig. Q 3b)	14	CO2	L4	2.1.3
	Unit 2				

4a)	A shaft has 3 disturbing masses in the single plane with radii of rotation r_1, r_2 and r_3 and angular positions θ_1, θ_2 and θ_3. Discuss how the system will be balanced by adding another balancing mass in the same plane.	8	CO5	L2	1.4.1
4b)	Determine the required input torque on the crank AB of the reciprocating engine mechanism for the static equilibrium when applied piston load is 1000 N. The lengths of crank AB and connecting rod BC are 100 mm and 300 mm respectively and crank has turned through 60° from I.D.C.	12	CO3	L3	2.4.1
5a)	Explain with neat sketch i) equilibrium of two force member ii) equilibrium of three force member iii) member with two forces and applied torque.	8	CO3	L2	1.2.1
5b)	An over drive for a vehicle consists of an epicyclic gear train, as shown in Fig. Q5b), with compound planets B-C. B has 15 teeth and meshes with an annulus A which has 60 teeth. The planet C has 20 teeth and meshes with the sun wheel D which is fixed. The annulus is keyed to the propeller shaft Y which rotates at 740 rad/s. The spider which carries the pins upon which the planets revolve, is driven directly from main gear box by shaft X, this shaft being relatively free to rotate with respect to wheel D. Find the speed of shaft X, when all the teeth have the same module. When the engine develops 130 kW, what is the holding torque on the wheel D? Assume 100 per cent efficiency throughout.  Fig Q 5b) Epicyclic gear train	12	CO4	L4	2.1.3
6a)	The pinion on the lay shaft drives gear on the main shaft of automobile gear box. The contact between pair of in volute teeth begins at one point and ends at other point. Obtain an expression for path of contact between pair of involute teeth.	8	CO4	L3	1.3.1

6b)	The A, B, C & D are four masses carried by a rotating shaft at radius100, 125, 200 & 150 mm respectively. The planes in which masses revolve are spaced 600 mm apart & masses B, C & D are 10, 5 and 4 kg respectively. Find the required mass A & relative angular positions of the four masses to keep the shaft in the dynamic balance.	12	CO5	L3	2.4.1
	Unit 3				
7a)	In a single cylinder automotive engine spherical follower is operated by a disc cam. If the follower moves with simple harmonic motion then obtain an expression for velocity and acceleration during its out and return strokes.	8	CO6	L2	1.3.1
7b)	Design a cam to raise a valve with simple harmonic motion through 50 mm in 1/3 of a revolution, keep if fully raised through 1/12 revolution and to lower it with harmonic motion in 1/6 revolution. The valve remains closed during the rest of the revolution. The diameter of the roller is 20 mm and the minimum radius of the cam is 25 mm. The diameter of the camshaft is 25 mm. The axis of the valve rod passes through the axis of the camshaft. If the camshaft rotates at uniform speed of 100 rpm, find the maximum velocity and acceleration of a valve during raising and lowering.	12	CO6	L3	2.1.2
8a)	Discuss with a neat sketch the axis of spin, axis of couple, axis of precession and precessional angular motion by considering the disc is spinning about X-axis. Obtain the expression for precessional angular motion.	8	CO7	L2	1.2.1
8b)	The turbine rotor of a ship has a mass of 3500 kg. It has a radius of gyration of 0.45 m and a speed of 3000 rpm clockwise when looking from stern. Determine the gyroscopic couple and its effect upon the ship: i) when the ship is steering to the left on a curve of 100 m radius at a speed of 36 km/h ii) when the ship is pitching in a simple harmonic motion, the bow falling with its maximum velocity. The period of pitching is 40 seconds and the total angular displacement between the two extreme positions of pitching is 12 degrees.	12	CO7	L3	1.2.1





BL – Bloom's Taxonomy Levels (1- Remembering, 2- Understanding, 3 – Applying, 4 – Analysing, 5 – Evaluating, 6 - Creating)
CO – Course Outcomes
PO – Program Outcomes; PI Code – Performance Indicator Code

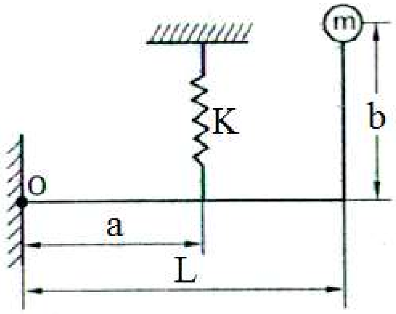
Course Name: Mechanical Vibrations

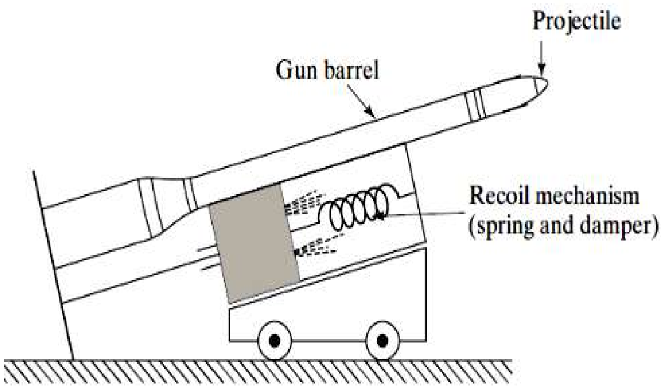
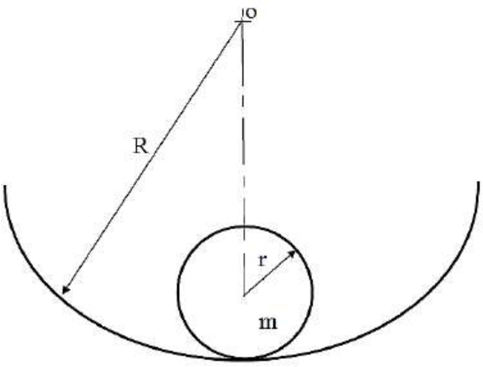
Course Outcomes (CO):

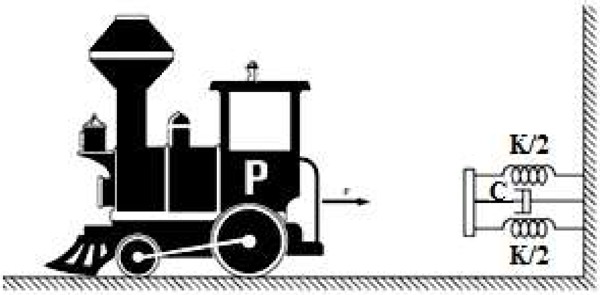
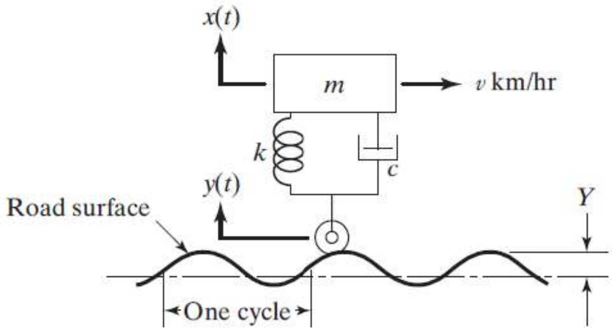
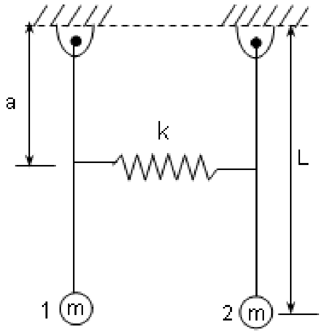
1. Determine the natural frequency of undamped free vibrations of single degree of freedom systems by formulating mathematical model of physical systems.
2. Analyse the response of damped systems for different amount of damping and compute the natural frequency of damped free vibration of mechanical systems.
3. Solve a problem related to whirling of shaft with rotor having some eccentricity.
4. Investigate the response of vibrating systems under forced harmonic excitations and explain the effect of magnification factor, vibration isolation and transmissibility on vibrating system.
5. Evaluate the natural frequencies and mode shapes of two degrees of freedom vibration systems and design vibration absorbers.
6. Determine the natural frequencies and mode shapes for multi-degree of freedom vibrating systems.
7. Explain vibration analysis techniques and noise measuring techniques to diagnose faults in machinery.

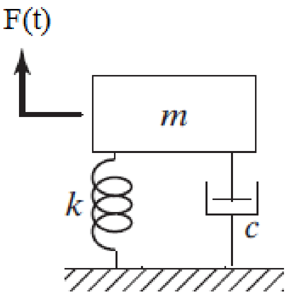
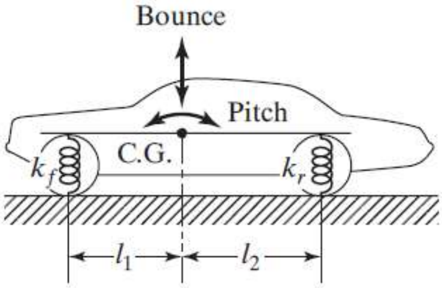
Model Question Paper
Total Duration (H:M): 3:00
Course: Mechanical Vibrations
Maximum Marks: 100

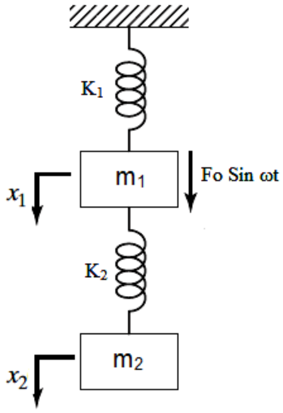
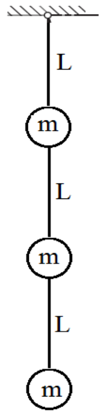
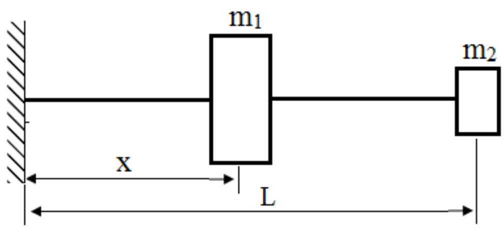
Note: *i) Answer any two full questions for Unit-1, any two full questions from Unit-II and any one full question from Unit-III*

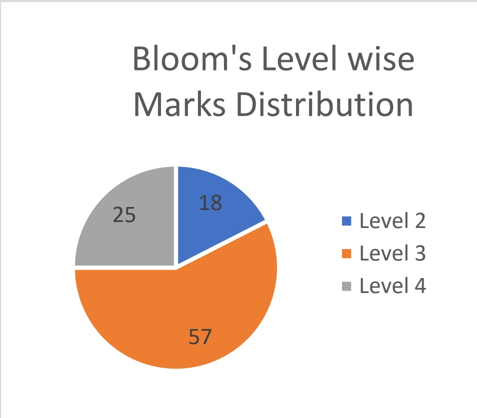
Q. No.	Questions	Marks	CO	BL	PI
	Unit I				
1 a)	An inverted pendulum as shown in Fig. Q 1(a) is pivoted at point O. Assume small oscillations and neglect the mass of the rod. Obtain the condition for the system to vibrate. Develop 1 and 2 dof mathematical model of a car  Fig.Q1(a)	10	CO1	L3	2.1.3
1 b)	A gun barrel shown in Fig. Q 1(b) having mass 560 kg is designed with the following data. Initial recoil velocity of 36 m/s and recoil distance on firing 1.5m. Determine i) Spring constant ii) Critical damping coefficient	10	CO2	L3	2.1.3

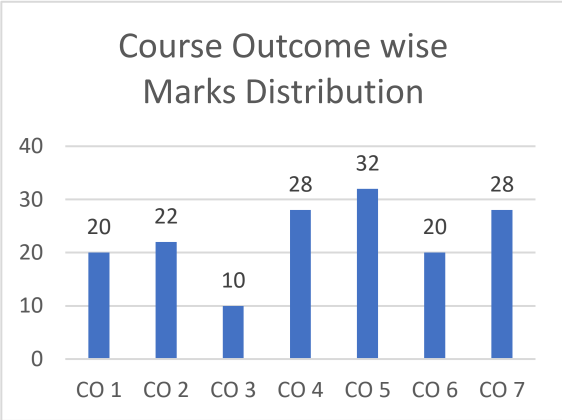
	of the dashpot which is engaged at the end of the recoil stoke. iii) Time required for the barrel to return to a position of 0.12 m from its initial position.  Fig.Q1(b)				
2 a)	A cylinder of mass 'm' and radius 'r' rolls without slipping on a cylindrical surface of radius R as shown in Fig. Q 2(a). Find the natural frequency for small vibrations.  Fig.Q2(a)	10	CO1	L3	2.1.3
2 b)	A rotor of mass 4 kg is mounted midway between bearings which may be assumed to be simple supports. The bearing span is 480 mm. The shaft is of 9 mm diameter and is horizontal. The center of gravity of the disc is displaced 3 mm away from the geometric center of rotor. The equivalent viscous damping at the center of the disc and shaft may be assumed as 49 N-S/m. The shaft rotates at 760 rpm. Take E= $2x10^{11}N/m^2$. Determine i) The critical speed of the shaft ii) Deflection of the shaft iii) Dynamic load on the bearings iv) The maximum stress in the shaft. v) Identify the parameters to reduce the stress in the shaft. Use any one parameter and reduce the stress to its 50%.	10	CO3	L4	2.1.3
3 a)	Explain any four instruments used for measuring, assessing and analyzing the noise output of machines.	08	CO7	L2	1.4.1
3 b)	A railroad car of mass 2,000 kg traveling at a velocity 10 m/s is stopped at the end of the tracks by a spring-damper system, as shown in Fig. Q3(b). The stiffness of each spring (K/2) is 40 N/mm and the damping constant is 20N-s/mm. Determine i) Undamped and damped natural frequency ii) Damping factor iii) The maximum displacement of the car after engaging the springs and damper.	12	CO2	L4	2.1.2

	 Fig.Q3(b)				
	Unit II				
4 a)	An automobile trailer that can vibrate in the vertical direction while traveling over a rough road is modeled as shown in Fig. Q 4(a). It has a vertical natural frequency of 100 cpm. It is driven along a road whose elevation varies approximately by a sine wave of amplitude 50 mm. The distance along the road between the peaks is 30 m. The damping ratio of shock absorbers is 0.2. Determine the amplitude of vibration of the car at a speed of 50 km/hr. Suggest possible methods of improving the design for a more comfortable ride of the passengers.  Fig. Q 4(a)	10	CO4	L4	2.1.3
4 b)	Determine the two natural frequencies for small oscillations of the pendulum shown in Fig. Q 4(b). Assume the rods are mass less and rigid. Take K = 1 kN/m, L = 0.75 m, a = 0.4 m, m_1 = 3 kg, m_2 = 5 kg.  Fig. Q 4(b)	10	CO5	L3	2.1.2
5 a)	A machine of mass 150 kg supported on springs of total stiffness 1050 kN/m is modelled as shown in Fig. Q 5(a). It has an excitation force of 525 N at a speed of 6000 rpm. The damping factor of the system is 0.3. Determine, i) The amplitude caused by the unbalance and its phase angle ii) The transmissibility iii) The actual force transmitted and its phase angle.	10	CO4	L3	3.1.6

	 Fig. Q 5(a)				
5 b)	Model the car shown in Fig. Q 5(b) and determine the pitch (angular motion) and bounce (up-and-down linear motion) frequencies and the location of oscillation centers (nodes) with the following data. Mass (m) = 1000 kg, radius of gyration (r) = 0.9 m, distance between front axle and C.G. (l_1) = 1.0 m, distance between rear axle and C.G. (l_2) = 1.5 m, front spring stiffness (k_f) = 18 kN/m, rear spring stiffness (k_r) = 22 kN/m.  Fig. Q 5(b)	10	CO5	L3	2.3.1
6 a)	A machine weighing 750 N is mounted on springs of 1200 kN/m stiffness with damping factor of 0.2. A piston within the machine weighing 20 N has a reciprocating motion with a stroke of 0.075 m and a speed of 3000 rpm. Assume the motion of the piston to be harmonic. Determine, i) Amplitude of motion of the machine and its phase angle w.r.t. the exciting force. ii) The transmissibility, the force transmitted to the foundation and its phase angle w.r.t. the exciting force. iii) Has the vibration isolation achieved, if so how? iv) Explain the effect of increasing the operating speed of the system on isolation.	08	CO4	L4	2.1.3
6 b)	The vibration absorber is shown in Fig. Q 6(b). Show that amplitude of vibration for the main system is given by $X_1 = \frac{(K_2 - m_2\omega^2)F_o}{m_1 m_2 \omega^4 - [m_1 k_2 + m_2(k_1 + k_2)]\omega^2 + k_1 k_2}$ A reciprocating machine weighing 25 kg running at 6000 rpm after installation has natural frequency very close to the forcing frequency of vibrating system. Design dynamic absorber of the nearest frequency of the system which is to be at least 20% from the excitation frequency.	12	CO5	L3	2.1.3

	 Fig. Q 6(b)				
	Unit III				
7 a)	Determine the fundamental natural frequency for the triple pendulum shown in Fig. Q 7(a) using matrix iteration method. Take $a_{11} = a_{12} = a_{13} = L/3mg$, $a_{22} = a_{23} = 5L/6mg$ and $a_{33} = 11\ L/6mg$.  Fig. Q 7(a)	10	CO6	L3	2.1.3
7 b)	Find the fundamental natural frequency of transverse vibration for the system shown in Fig. Q 7(b) using Rayleigh's method. Take m_1 =80 kg, m_2 = 40 kg, x=0.25m, L=0.4 m, E=200 GPa and I =4×10^{-7} m^4.  Fig. Q 7(b)	10	CO6	L3	2.3.1
8 a)	Explain in detail the procedure of experimental modal analysis with necessary hardware components.	10	CO7	L2	1.4.1
8 b)	Explain with sketch seismic instruments. It is desired to measure the maximum acceleration of a machine part which vibrates violently with a frequency of 700 cpm. Accelerometer attached to it has a mass of 0.05 kg and spring constant of 1800 N/m. Total travel of the accelerometer indicator is 8.2 mm. Determine the maximum amplitude and maximum acceleration of the vibrating part.	10	CO7	L2	1.4.1





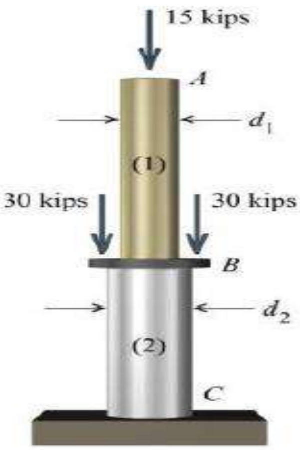
BL – Bloom's Taxonomy Levels (1- Remembering, 2- Understanding, 3 – Applying, 4 – Analysing, 5 – Evaluating, 6 - Creating)
CO – Course Outcomes
PO – Program Outcomes; PI Code – Performance Indicator Code

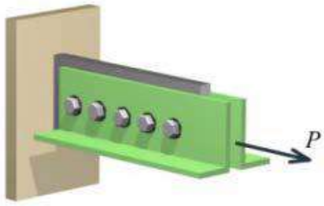
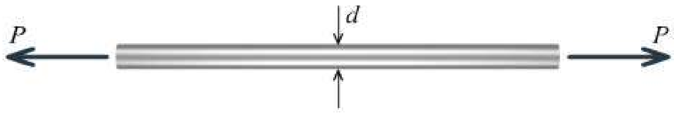
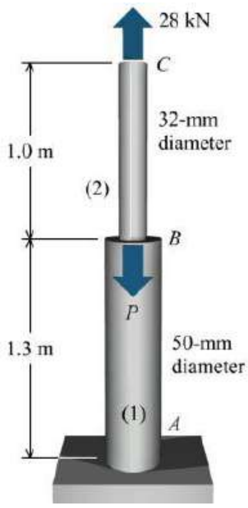
Course Name: Mechanics of Materials

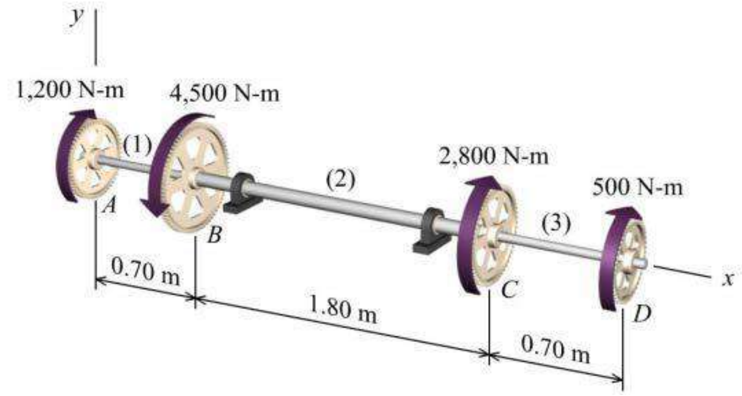
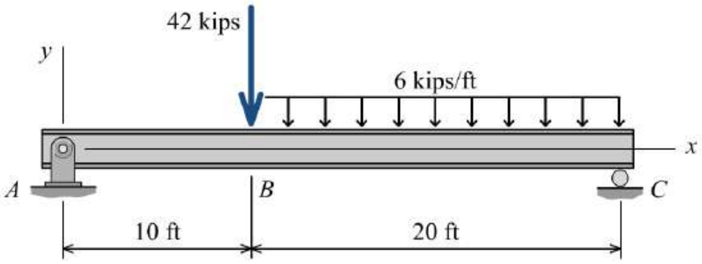
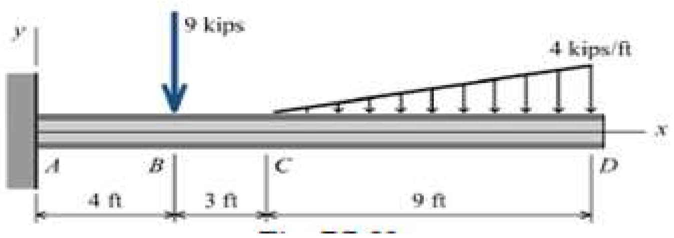
Course Outcomes (CO):

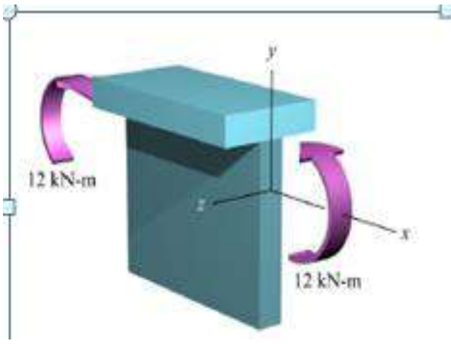
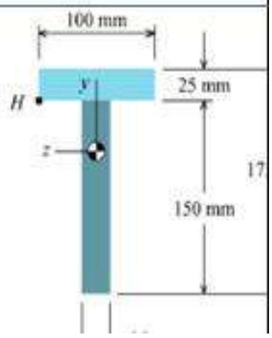
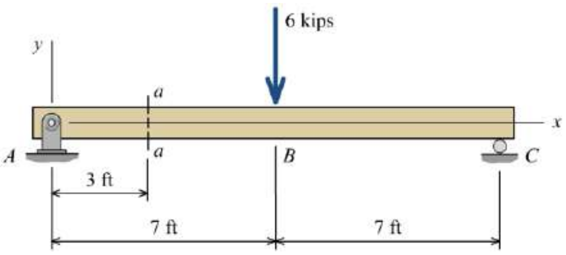
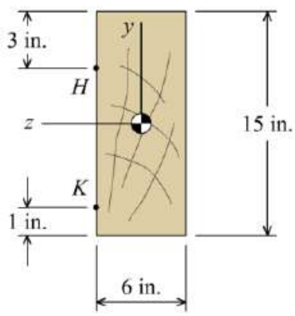
1. Analyze the state of internal effects caused by external loads acting on real bodies that undergoes deformation (stress & strain).
2. Determine the strength and characteristics of materials and understand the design uncertainties involved in design problem.
3. Compute the deformation of variety of structural members and design components subjected to axial loading.
4. Analyze Torsional stress and angle of twist in circular shafts used for power transformation.
5. Draw shear and moment diagrams of simple beams subjected to various loading conditions.
6. Apply the flexural formula to simple structures to calculate the bending stress.
7. Determine the shear stresses produced by non uniform bending.
8. Compute deflection of beams.

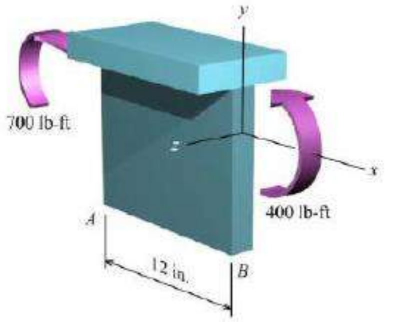
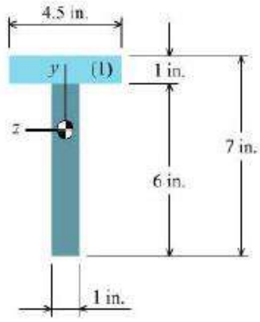
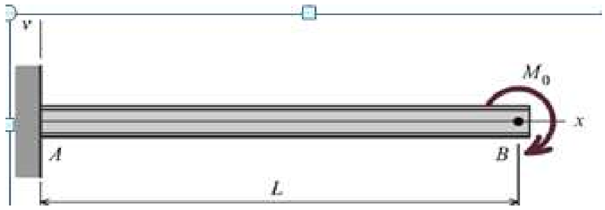
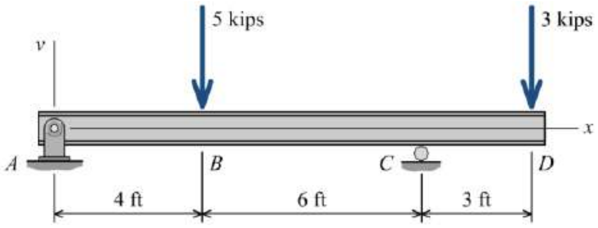
Model Question Paper
Total Duration (H:M):3:00
Course :Mechanics of Materials
Maximum Marks :100

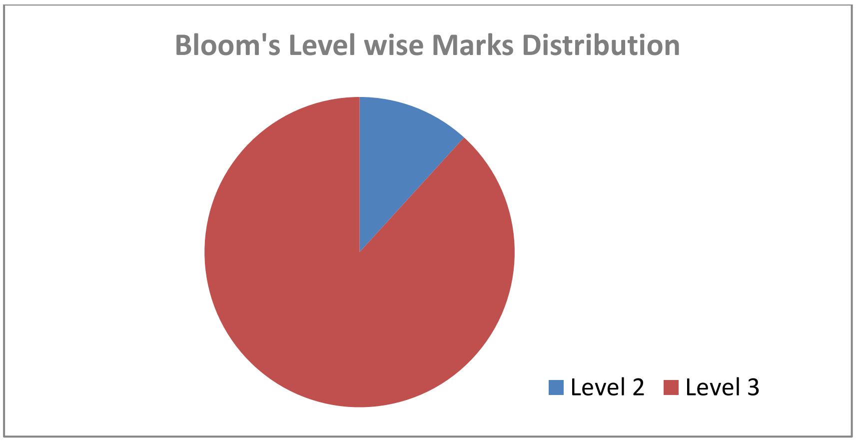
Q. No.	Questions	Marks	CO	BL	PI
1a	Two solid cylindrical rods (1) and (2) are joined together at flange *B* and loaded, as shown in Figure Q.1a. The diameter of rod (1) is 1.75 in. and the diameter of rod (2) is 2.50 in. Determine the normal stresses in rods (1) and (2).  Figure Q.1a	10	CO1	L3	1.3.1
1b	The five-bolt connection shown in Figure Q.1b must support an applied load of *P* = 265 kN. If the average shear stress in the bolts must be limited to 120 MPa, determine the minimum bolt diameter that may be used for this connection.	05	CO1	L3	1.3.1

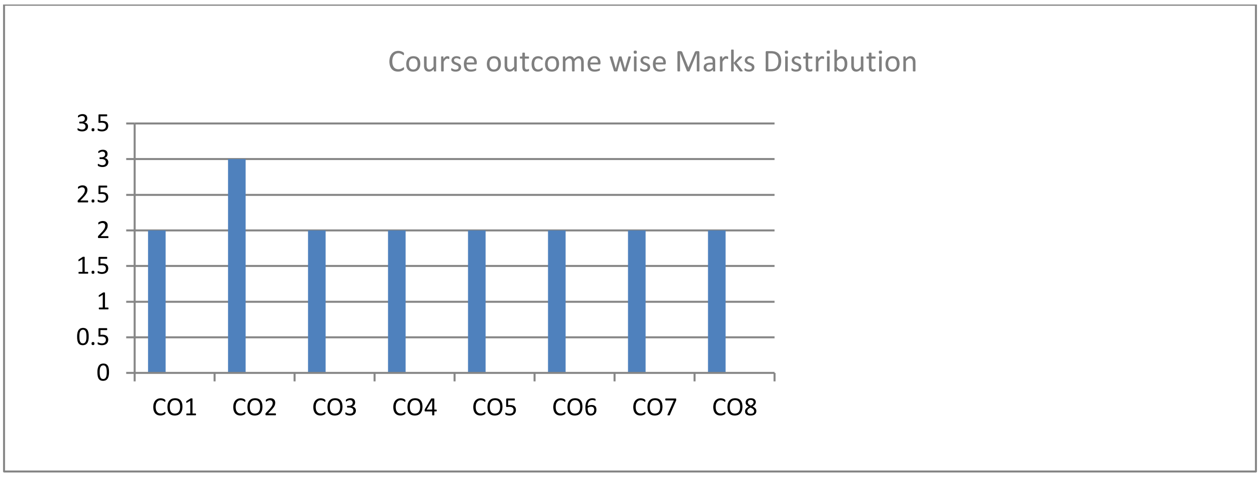
	 Figure Q.1b				
1c	State the Hook's law. Neatly draw the Stress-strain diagram for Steel indicating all silent points and zones on it.	05	CO2	L2	1.3.1
2a	At an axial load of 22 kN, a 45-mm-wide × 15-mm-thick polyimide polymer bar elongates 3.0 mm while the bar width contracts 0.25 mm. The bar is 200 mm long. At the 22-kN load, the stress in the polymer bar is less than its proportional limit. Determine: (a) the modulus of elasticity, (b) Poisson's ratio, (c) the change in the bar thickness	10	CO2	L3	1.3.1
2b	A solid circular rod with a diameter of *d* = 16 mm is shown in Figure Q.2b. The rod is made of an aluminum alloy that has an elastic modulus of *E* = 72 GPa and Poisson's ratio of ν = 0.33. When subjected to the axial load *P*, the diameter of the rod decreases by 0.024 mm. Determine the magnitude of load *P*  Figure Q.2b	10	CO2	L3	1.3.1
3a	With standard notations derive the expression for deformation of axially loaded bars of uniform cross-section	10	CO3	L3	1.3.1
3b	Aluminum [*E* = 70 GPa] member *ABC* supports a load of 28 kN, as shown in Figure Q.3b. Determine: (a) the value of load *P* such that the deflection of joint *C* is zero. (b) the corresponding deflection of joint *B*.  Figure Q.3b	10	CO3	L3	1.3.1
4a	A solid steel [*G* = 80 GPa] shaft of variable diameter is subjected to the torques shown in Figure Q.4a. The diameter of the shaft in segments (1) and (3) is 50 mm, and the diameter of the shaft in segment (2) is 80 mm. The bearings shown allow the shaft to turn freely. Determine the maximum shear stress in the compound shaft.	10	CO4	L3	1.3.1

	 Figure Q.4a				
4b	A tubular steel [G = 80 GPa] shaft is being designed to transmit 150 kW at 30 Hz. The maximum shear stress in the shaft must not exceed 80 MPa and the angle of twist is not to exceed 6° in a 4-m length. Determine the minimum permissible outside diameter if the ratio of the inside diameter to the outside diameter is 0.80.	10	CO4	L3	1.3.1
5a	For the simply supported beam subjected to the loading shown in figure Q. 5a, (a) Derive equations for the shear force V and the bending moment M for any location in the beam. (Place the origin at point A.) (b) Plot the shear-force and bending-moment diagrams for the beam using the derived functions. (c) Report the maximum bending moment and its location.  Figure Q. 5a	10	CO5	L3	1.3.1
5b	Use the graphical method to construct the shear-force and bending-moment diagrams for the beam shown in figure Q.5b . Label all significant points on each diagram and identify the maximum moments along with their respective locations. Clearly differentiate straight-line and curved portions of the diagrams.  Figure Q.5b	10	CO5	L3	1.3.1
6a	A beam having a tee-shaped cross section is subjected to equal 12 kN-m bending moments, as shown in Figure Q.6a. The cross-sectional	10	CO6	L3	1.3.1

	dimensions of the beam are shown in Figure Q.6b.Determine: (a) the centroid location, the moment of inertia about the z axis. (b) the maximum bending stress produced in the cross section. State whether the stress is tension or compression.  Figure Q.6a  Figure Q.6b				
6b	Derive the flexural formula for a beam subjected to pure bending.	10	CO6	L2	1.3.1
7a	A 14-ft long simply supported timber beam carries a 6-kip concentrated load at mid span, as shown in Figure Q.7*a*. The cross-sectional dimensions of the timber are shown in Figure Q.7b. (a) At section *a–a*, determine the magnitude of the shear stress in the beam at point *H.* (b) Determine the maximum horizontal shear stress that occurs in the beam at any location within the 14-ft span length.  Figure Q.7a.  Figure Q.7b.	10	CO7	L3	1.3.1
7b	For the following problems, a beam segment subjected to internal bending moments at sections A and B is shown along with a sketch of the cross-sectional dimensions. Determine (a) the resultant forces acting in the x direction on the specified area at sections A and B and show these resultant forces on the sketch.	10	CO7	L3	1.3.1

	(b) Is the specified area in equilibrium with respect to forces acting in the x direction? If not, determine the horizontal force required to satisfy equilibrium for the specified area and show the location and direction of this force on the sketch  				
8a	For the loading shown in Figure Q. 8a, use the double-integration method to determine (a) the equation of the elastic curve for the cantilever beam, (b) the deflection at the free end. Assume that EI is constant for each beam.  Figure Q. 8a	10	CO8	L3	1.3.1
8b	For the beam and loading shown in Figure Q.8b, use discontinuity functions to compute the deflection of the beam at *D*. Assume a constant value of EI = 1,750 kip-ft^2 for the beam.  Figure Q.8b	10	CO8	L3	1.3.1





BL – Bloom's Taxonomy Levels (1- Remembering, 2- Understanding, 3 – Applying, 4 – Analysing, 5 – Evaluating, 6 - Creating)
CO – Course Outcomes
PO – Program Outcomes; PI Code – Performance Indicator Code