THE OPEN UNIVERSITY OF SRI LANKA
Bachelor of Technology – Level 3
CEX 3231 – Structural Analysis & Design 1
Final Examination – 2016/2017
Time Allowed 3 hours

30th November 2017 | Time – 9.30 – 12.30 hrs

Answer any Five questions
Please write answers clearly showing any derivations required and state necessary assumptions.

Q1a). State five idealizations used in analyzing trusses. Discuss their validity respecting real trusses. (5 Marks)

b). The truss shown in Figure Q1 is pin jointed to a support at L1, on a roller support at L2. Determine member forces in all the members of the truss by the 'method of joints' for the loads given (10 Marks)

c). Determine the member forces of M1U2 and L1M2 by method of section to verify the results obtained in part b). (5 Marks)

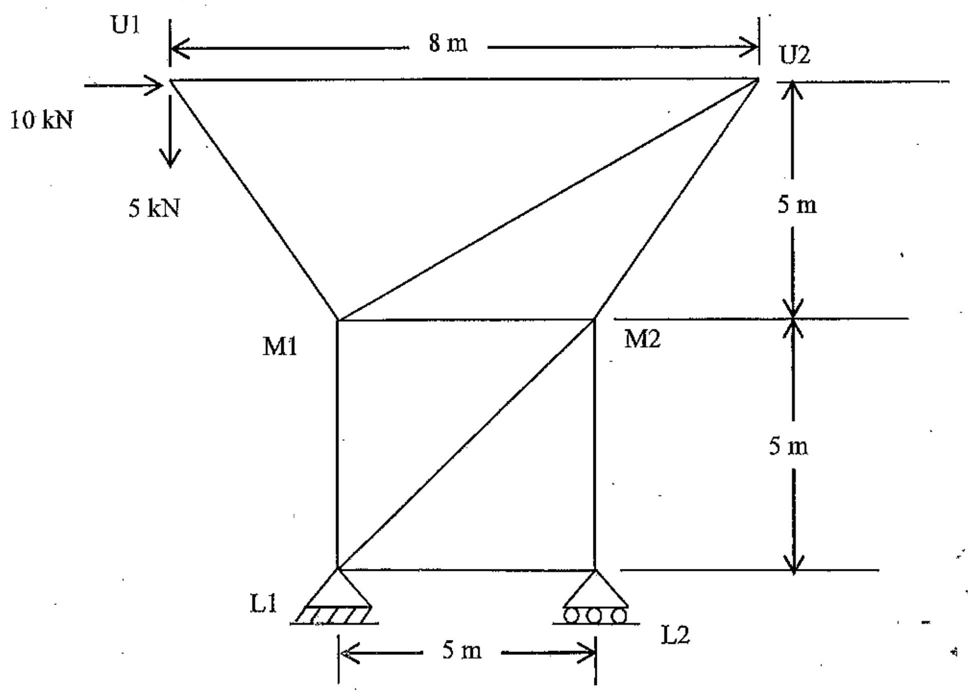


Figure Q1

Q2.) a). State three methods that can be used to find a deflections of the statically determinant trusses. (3 Marks)

b). The truss shown in Figure Q2 is pin jointed to a support at L1 and on a roller support at L2. The truss is loaded as given in Figure Q2.

i). Calculate the vertical deflection of the joint U1. (8 Marks)

ii). Calculate the horizontal deflection of the joint U1. (6 Marks)

iii). Calculate the value and the angle of the joint U1 deflection. (3 Marks)

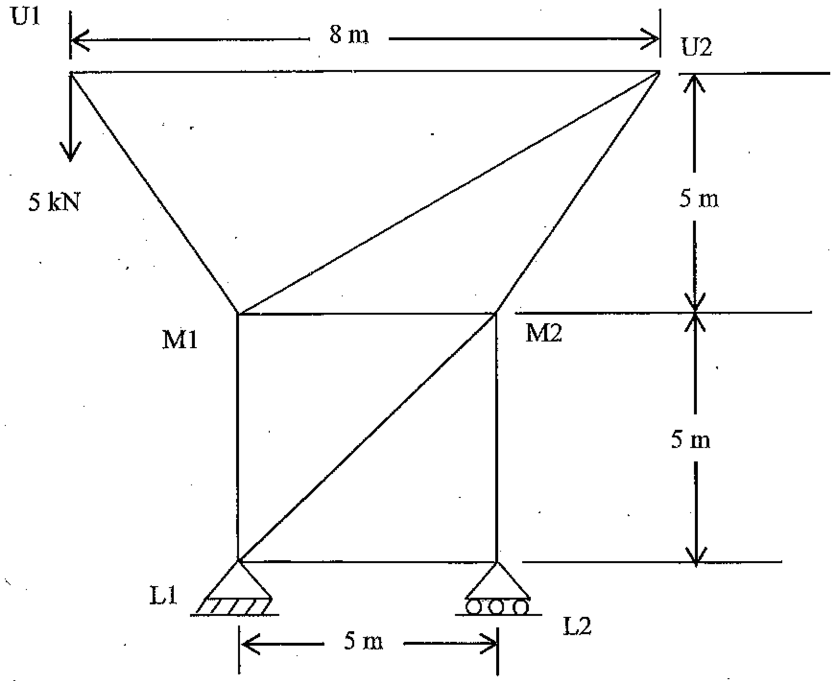


Figure Q2

Q3) Figure Q3 shows a propped cantilever beam with a hinge at C.

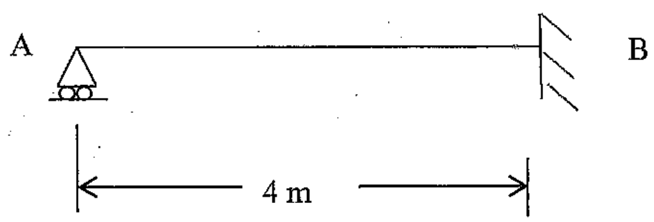


Figure Q3

a). Show that the beam given in Figure Q3 is statically indeterminate. Also show that by introducing one hinge the beam can be changed to Statically Determinate structure. What are the implications if two hinges are introduced? (3 Marks) b). Draw Influence lines for the followings after introducing a hinge 1m left to the fixed support of the beam.

i). Reaction of A

ii). support moment at B

iii). Bending moment at mid span of AB (10 Marks)

c). If following loads are moving on the beam, find the maximum Bending Moment of mid span AB.

i). Two concentrated loads of 5 kN each at 2 m apart.

ii). A Uniformly distributed load of 2 kN /m and 3 m in length.

(7 Marks)

Data for Q4 and Q5

Table Q4/Q5 shows the analytical results of the truss given in Figure Q1

Member	Member Force (kN)	Tension or Compression
L1L2	10	Tension
L1M1	8	Compression
L1M2	12	Tension
L2M2	7	Compression
M1M2	15	Tension
M1U1	12	Tension
M1U2	8	Tension
M2U2	10	Compression
U1U2	12	Compression

Table Q4/Q5

All the members are connected to a 12 mm thickness gusset plate with M 18 bolts (at least two bolts per each connection). Equal angle steel sections are available with standard sections and it is proposed to use single angle members and double angle back to back sections for the design.

Q4 a). i) With appropriate figure of single angle member connected to a gusset plate using one bolt line show

Connected leg, unconnected leg, Gross area, Net Area and Effective area.

(4 Marks)

b). i). Check the suitability of 70 x 70 x 6 EA section for the tension members (6 Marks)

ii). Now it is proposed to replace single angle member with back to back double angle section. Determine suitable back to back double angle section for the tension members. (5 Marks)

c). If additional 1 kNm moment is applied at mid span of the each tension member check the suitability of single angle section checked in b). i) (5 marks)

Q5 a). A compression member of a truss can fail due to buckling or crushing. Brief the design criteria of the compression member considering both failure modes. (6 Marks)

b). i). Check the suitability of a single angle 70 x 70 x 6 EA section for compression members. (4 Marks)

ii). Now it is proposed to replace the single angle members with back to back double angle sections. Design the compression member with suitable back to back double angle member. (6 Marks)

The radius of gyration of double angle member is given by

$r_{xx}\text{(double)} = r_{xx}$

$r_{yy}^2\text{(double)} = r_{yy}^2 + (c_y + t/2)^2$

Where r_{xx}, r_{yy} and c_y have their standard meanings and thickness of gusset plate is taken as 12 mm.

c). Explain why slenderness ratio should be checked for axis vv other than the horizontal and vertical axes (xx and yy) for a single angle member and no need to check slenderness ratio of vv axis in double angle members. (4 Marks)

Q6 a). State the difference between Single shear connection and double shear connection of the bolted joint used in steel roof truss with neat sketch. (4 Marks)

b). A single angle member (70 x 70 x 8 EA) is proposed to connect with a gusset plate (12 mm thick) and it was found that 4 number of 18 M bolts are required for the connection.

i). Sketch two arrangements that can be used for this connection. (2 Marks)

ii). Detail each arrangement and state which arrangement is more appropriate with the reasons. (Assume members are cut by machine flame) (6 Marks)

c). A cantilever beam of 5 m effective span is subjected to 10 kN/m dead load and 6 kN/m imposed load.

i). Find the design load and maximum bending moment (2 marks)

ii). Design the member with 457 x 152 x 82 UB section. (6 Marks)

457 x 152 x 82 UB Properties : D – 457.2 mm, B – 153.5 mm, T – 18.9 mm , t – 10.7 mm, A – 104.4 cm^2, Zxx – 1555 cm^3, Zyy – 142.5 cm^3, r_{xx} = 18.6 cm , r_{yy} = 3.24 cm

Q7 a). Explain why basic wind speed of Post Disastar structures is higher than Normal structures. (3 Marks)

b). State the factors that should be used to modify the basic wind speed to find design wind speed. (4 Marks) c). A steel column is joined at the top and bottom with fixed supports. The column has cross sectional area A and elastic modulus of steel is E

i). show that effective length of the column is nearly 0.5 L using first principals, where L is original length. (6 Marks)

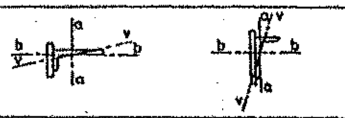
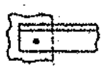
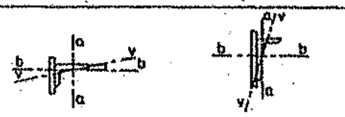
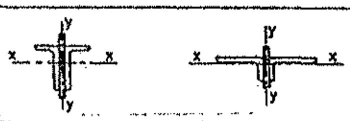
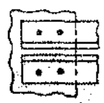
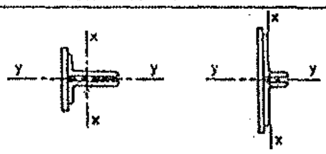
ii). If length of the member is 2 m find the compressive capacity of the column. load applied without any eccentricity. The column has 0.03 m x 0.02 m cross section. (4 Marks)

Allowable compressive stress – 150 N/mm^2
Elastic Modulus of steel – 200 GPa

DATA SHEETS

a	T	M	r1	r2	A	C of G	Moment Of Inertia			Radius Of Gyration			Z
						Cx, Cy	X-X, Y-Y	U-U	V-V	X-X, Y-Y	U-U	V-V	
mm	mm	kg	mm	mm	cm^2	cm	cm^4	cm^4	cm^4	cm	cm	cm	cm^3
50 x 50	5	3.77	7,0	2,4	4.80	1.40	11.0	17.4	4.54	1.51	1.90	0.97	3.05
	6	4.47	7,0	2,4	5.69	1.45	12.8	20.4	5.33	1.50	1.89	0.97	3.61
	7	5.82	7,0	2,4	7.41	1.52	16.3	25.7	6.87	1.48	1.86	0.96	4.68
60 x 60	5	4.57	8,0	2,4	5.82	1.64	19.4	30.7	8.02	1.82	2.30	1.17	4.45
	6	5.42	8,0	2,4	6.91	1.69	22.8	36.2	9.43	1.82	2.29	1.17	5.29
	8	7.09	8,0	2,4	9.03	1.77	29.2	46.2	12.1	1.80	2.26	1.16	6..89
	10	8.69	8,0	2,4	11.1	1.85	34.9	55.1	14.8	1.78	2.23	1.16	8.41
70 x 70	6	6.38	9,0	2,4	8.13	1.93	36.9	58.5	15.2	2.13	2.68	1.37	7.27
	8	8.36	9,0	2,4	10.6	2.01	47.5	75.3	19.7	2.11	2.66	1.36	9.52
	10	10.3	9,0	2,4	13.1	2.09	57.2	90.5	23.9	2.09	2.63	1.35	11.7
80 x 80	6	7.34	10,0	4,8	9.35	2.17	55.8	88.5	23.1	2.44	3.08	1.57	9.57
	8	9.63	10,0	4,8	12.3	2.26	72.2	115	29.8	2.43	3.06	1.56	12.6
	10	11.9	10,0	4,8	15.1	2.34	87.5	139	36.3	2.41	3.03	1.55	15.4
90 x 90	6	8.3	11,0	4,8	10.6	2.41	80.3	127	33.3	2.76	3.47	1.78	12.2
	8	10.9	11,0	4,8	13.9	2.50	104	166	43.1	2.74	3.45	1.76	16.1
	10	13.4	11,0	4,8	17.1	2.58	127	201	52.6	2.72	3.42	1.76	19.8
	12	15.9	11,0	4,8	20.3	2.66	148	234	61.7	2.70	3.40	1.75	23.3
100x100	8	12.2	12,0	4,8	15.5	2.74	145	230	59.8	3.06	3.85	1.96	19.9
	12	17.8	12,0	4,8	22.7	2.90	207	328	85.7	3.02	3.80	1.94	29.1
	15	21.9	12,0	4,8	27.9	3.02	249	393	104	2.98	3.75	1.93	35.6

TABLE 15. ANGLE STRUTS

Connection	Sections and axes	Slenderness ratios (see notes 1 and 2)
		*vv axis:* $0.85L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $0.85L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$
 (See note 3)		*vv axis:* $1.0L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $1.0L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$ (See note 3)
 (See note 4)		*xx axis:* $0.85L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $1.0L_{yy}/r_{yy} + 10$
 (See note 4)		*xx axis:* $1.0L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $0.85L_{yy}/r_{yy}$ but $\geq 0.7L_{yy}/r_{yy} + 10$

NOTE 1. The length L is taken between the intersections of the centroidal axes or the intersections of the setting out lines of the bolts, irrespective of whether the strut is connected to a gusset or directly to another member.

NOTE 2. Intermediate lateral restraints reduce the value of L for buckling about the relevant axes. For single angle members, L_{vv} is taken between lateral restraints perpendicular to either aa or bb.

NOTE 3. For single angles connected by one bolt, the allowable stress is also reduced to 80 per cent of that for an axially loaded member.

NOTE 4. Double angles are interconnected back-to-back to satisfy Clause 37.

TABLE 2. ALLOWABLE STRESS p_{bc} OR p_{bt} IN BENDING
(See also Clauses 19 and 20 and Tables 3 and 4)

Form	Grade	Thickness of material	p_{bc} or p_{bt}
Sections, bars, plates, wide flats and hot rolled hollow sections. Compound beams composed of rolled sections plated, with thickness of plate. Double channel sections forming a symmetrical I-section which acts as an integral unit.	43	≤ 40 >40 but ≤ 100	180 165
	50	≤ 63 >63 but ≤ 100	230 215
	55	≤ 25	280
Plate girders with single or multiple webs	43	≤ 40 >40 but ≤ 100	170 155
	50	≤ 63 >63 but ≤ 100	215 200
	55	≤ 25	265
Slab bases	All steels		185

TABLE 17a. ALLOWABLE STRESS p_c ON GROSS SECTION FOR AXIAL COMPRESSION

As altered Dec. 1989

l/r	p_c (N/mm²) for grade 43 steel									
	0	1	2	3	4	5	6	7	8	9
0	170	169	169	168	168	167	167	166	166	165
10	165	164	164	163	163	162	162	161	160	160
20	159	159	158	158	157	157	156	156	155	155
30	154	154	153	153	153	152	152	151	151	150
40	150	149	149	148	148	147	146	146	145	144
50	144	143	142	141	140	139	139	138	137	136
60	135	134	133	131	130	129	128	127	126	124
70	123	122	120	119	118	116	115	114	112	111
80	109	108	107	105	104	102	101	100	98	97
90	95	94	93	91	90	89	87	86	85	84
100	82	81	80	79	78	77	75	74	73	72
110	71	70	69	68	67	66	65	64	63	62
120	62	61	60	59	58	57	57	56	55	54
130	54	53	52	51	51	50	49	49	48	47
140	47	46	46	45	45	44	43	43	42	42
150	41	41	40	40	39	39	38	38	38	37
160	37	36	36	35	35	35	34	34	33	33
170	33	32	32	32	31	31	31	30	30	30
180	29	29	29	28	28	28	28	27	27	27
190	26	26	26	26	25	25	25	25	24	24
200	24	24	24	23	23	23	23	22	22	22
210	22	22	21	21	21	21	21	20	20	20
220	20	20	20	19	19	19	19	19	19	18
230	18	18	18	18	18	18	17	17	17	17
240	17	17	17	16	16	16	16	16	16	16
250	16	15	15	15	15	15	15	15	15	15
300	11	11	11	11	11	11	10	10	10	10
350	8	8	8	8	8	8	8	8	8	8

NOTE 1. Intermediate values may be obtained by linear interpolation.

NOTE 2. For material over 40 mm thick refer to subclause 30a.

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TABLE 3 *a*. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm^2) FOR CASE A OF CLAUSE 19*a*(2) FOR GRADE 43 STEEL

l/r_y	*D/T*									
	5	10	15	20	25	30	35	40	45	50
40	180	180	180	180	180	180	180	180	180	180
45	180	180	180	180	180	180	180	180	180	180
50	180	180	180	180	180	180	180	180	180	180
55	180	180	180	178	176	175	174	174	173	173
60	180	180	176	172	170	169	168	167	167	166
65	180	180	172	167	164	163	162	161	160	160
70	180	177	167	162	159	157	156	155	154	154
75	180	174	163	157	154	151	150	149	148	147
80	180	171	159	153	148	146	144	143	142	141
85	180	168	156	148	143	140	138	137	136	135
90	180	165	152	144	139	135	133	131	130	129
95	180	162	148	140	134	130	127	125	124	123
100	180	160	145	136	129	125	122	119	118	117
105	180	157	142	132	125	120	116	114	112	111
110	180	155	139	128	120	115	111	108	106	105
115	178	152	136	124	116	110	106	103	101	99
120	177	150	133	120	112	106	101	98	96	95
130	[illegible]	146	127	113	104	97	94	91	89	88
140	[illegible]	142	121	107	97	92	88	85	83	81
150	168	138	116	100	92	87	82	79	77	75
160	166	134	111	96	88	82	77	74	72	70
170	163	130	106	92	84	77	73	69	67	65
180	161	126	102	89	80	73	69	65	63	60
190	158	123	97	85	76	70	65	61	59	56
200	156	119	95	82	73	66	62	58	55	53
210	154	116	92	79	70	63	58	55	52	50
220	151	113	90	77	67	61	56	52	49	47
230	149	110	87	74	65	58	53	49	47	44
240	147	107	85	72	62	56	51	47	44	42
250	145	104	83	69	60	53	48	45	42	40
260	143	101	80	67	58	51	46	43	40	38
270	141	98	78	65	56	49	45	41	38	36
280	139	96	76	63	54	48	43	39	37	35
290	137	94	75	61	52	46	41	38	35	33
300	135	93	73	60	51	44	40	36	34	32

Appendix - BS 449: Part2: 1969 Tables & Clause

from **BS 449 Table 10: Allowable maximum shear stress p_q**

Allowable maximum shear stress p_q for sections, bars, plates, wide flats and hot rolled sections of grade 43 steel:
For thickness ≤ 40 mm: 125 N/mm^2
For 40 < thickness ≤ 100 mm: 115 N/mm^2

BS 449 Table 20: Allowable stresses in Rivets and Bolts (N/mm^2)

Description of fasteners	Axial tension	Shear	Bearing
Power-driven rivets	100	100	300
Hand-driven rivets	80	80	250
Close tolerance and turned bolts	120	100	300
Bolts in clearance holes	120	80	250

BS 449 Table 20A : Allowable Bearing stresses on connected parts (N/mm^2)

Description of fasteners	Material of connected part		
	Grade 43	**Grade 50**	**Grade 55**
Power-driven rivets Close tolerance and turned bolts	300	420	480
Hand-driven rivets Bolts in clearance holes	250	350	400

BS 449 Table 21: Edge distance of Holes

Diameter of hole	Distance to sheared or hand flame cut edge	Distance to rolled, machine flame cut, sawn or planed edge
mm	mm	mm
39	68	62
36	62	56
33	56	50
30	50	44
26	42	36
24	38	32
22	34	30
20	30	28
18	28	26
16	26	24
14	24	22

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Spacing of Bolts

The BS 449 clause 52 gives the following parameters for positioning of bolts, based on clause 51 pertaining to rivets.

Minimum *pitch* (BS clause 51 b):
A minimum clearance should be available between adjacent bolts; this is specified in terms of the *pitch* i.e. distance between bolts as follows:

Minimum distance between centres of the bolts shall
$\not<$ [2.5 x nominal diameter of bolt].

Maximum pitch (BS clause 51 c):
There are a number of conditions given about the maximum distance between adjacent bolts. The main conditions are as follows: (please refer the BS for the complete specifications).

(i) The distance between centres of any two adjacent bolts that connect together elements of compression or tension members, shall
$\not>$ 32t or 300 mm, where t is the thickness of the thinner outside plate.

(ii) The distance between centres of two adjacent bolts in a line lying in the direction of stress, shall
$\not>$ 16 t or 200 mm in tension members, and
$\not>$ 12 t or 200 mm in the case of compression members.

(iii) The distance between any two consecutive bolts in a line adjacent or parallel to an edge of an outside plate
$\not>$ [100 mm + 4 t] or 200 mm in compression or tension members.

(iv) When bolts are staggered at equal intervals and the gauge does not exceed 75 mm, the distances between centres of bolts as specified in (ii) and (iii) above may be increased by 50 %.