THE OPEN UNIVERSITY OF SRI LANKA
Bachelor of Technology – Level 3
CVX3441– Structural Analysis & Design 1
Final Examination – 2019/2020
Time Allowed 3 hours

06th October 2020 Time – 9.30 – 12.30 hrs

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

Q1 Trusses are used specially in roofs and bridges.

a). Define the term "Null Members of the trusses" (2 Marks)

b). Identify the "Null Members" of given truss in Figure Q1. (2 Marks)

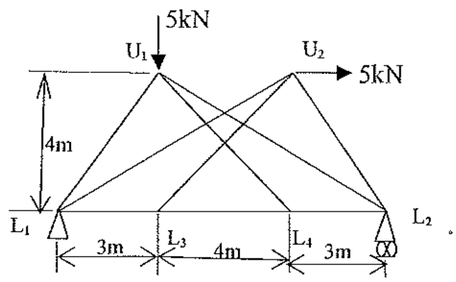


Figure Q1

c). Determine member forces in all the members of the truss given in Figure Q1 by 'Method of joints' or "Graphical method" for loads given. (by indicating the member forces are tension or compression).
Note – Members are connected only at joints L_1, L_2, L_3, L_4, U_1 and U_2.
(10 Marks)

d). Determine the member forces L_1U_2, L_2U_1 and L_2L_4 of the truss given in Q1 using "method of section" (6 Marks)

Q2.) a). State three methods that can be used to find a deflection of the statically determinant trusses. (1.5 Marks)

b). The truss shown in Figure Q2 pin supported at joints L1 and L2.

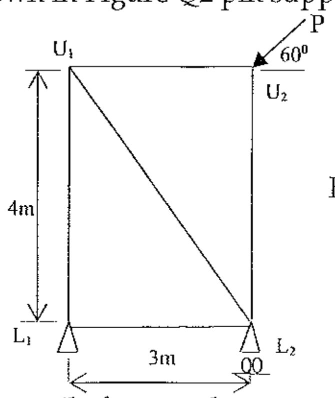


Figure Q2

If allowable tensile force and compressive force are 10 kN and 8 kN respectively find the maximum value for P. (8 Marks)

If allowable tensile force and compressive force are 10 kN and 8 kN respectively find the maximum value for P.
(8 Marks)

c).i). If allowable deflection of the joint U_2 is 5 mm, find the maximum value for P. Take Elastic Modulus of the material is 200 Mpa and all the members are made out with hollow sections of 50 mm x 50 mm with thickness 5 mm.
(3 Marks)

ii). Find the deflection at U_1 in mm if P = 5 kN (7.5 Marks)

Q3) Figure Q3-a shows a continuous beam of ABC

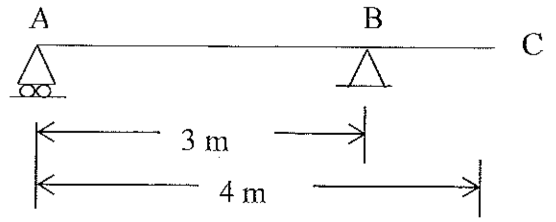


Figure Q3-a

a). Draw Influence lines for followings
i). Vertical Reaction of A
ii). Bending moment at mid span of AB (6 Marks)

b). If a uniformly distributed load of 2 kN /m and 2 m in length is moving on the beam, find the maximum Bending Moment of mid span AB. (4 Marks)

c). Three pin arch given in Figure Q3-b is subjected to given loads.

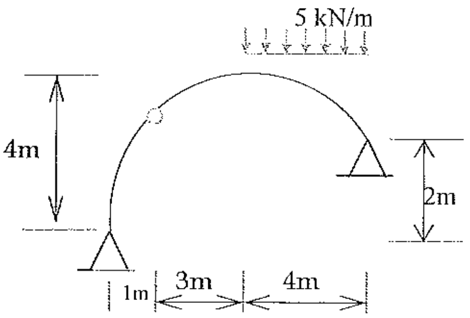


Figure Q3 – b

i). Find a general equation for the arch. (5 Marks)
ii). Find support reactions of the arch. (5 Marks)

Data for Q4 and Q5

Figure Q4-Q5 is shown a joint of a steel truss. Members are connected to a 12 mm thickness gusset plate with M 20 bolts (at least two bolts per each connections). Equal angle steel sections are available with standard sections and it is proposed to use single angle sections and double angle back to back sections. Two members are perpendicular to each other and member A makes 75^0 to the horizontal. 10 kN horizontal load and 5 kN vertical load are applied as shown in the Figure Q4-Q5. The lengths of member A and member B are given as 2 m and 3 m respectively.

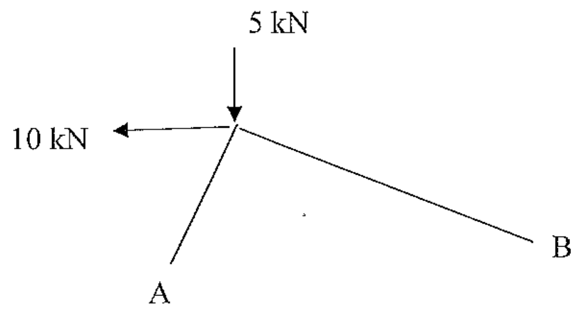


Figure Q4 – Q5

Q4) a). Define the term "eccentricity of the connection" and explain how the eccentricity is allowed in steel design.
(2 Marks)

b). i). Find the tension member of the joint with its member force. (2 Marks)
ii). Design the tension member with suitable single angle member. (Minimum Thickness - 8 mm) (6 Marks)
iii). Design the tension member with suitable back to back double angle member. (5 Marks)

c). If additional 5 kN load is applied perpendicular to the tension member at mid span check the suitability of single angle selected in b). ii). (5 marks)

Q5) a). Define the terms i). Buckling of struts, ii). Slenderness ratio, iii). Effect of slenderness ratio to the buckling of struts. (4 Marks)

b). i). Find the compression member of the joint with its member force. (1 Mark)
ii). Design the compression member with suitable single angle member. (Minimum Thickness - 8 mm) (6 Marks)
iii). Design the compression member with suitable back to back double angle Member. (6 Marks)

c). Explain why slenderness ratio should be checked for axes uu, xx and yy for single angle member but only xx and yy axes for double angle members.
(3 Marks)

Q6). (a).

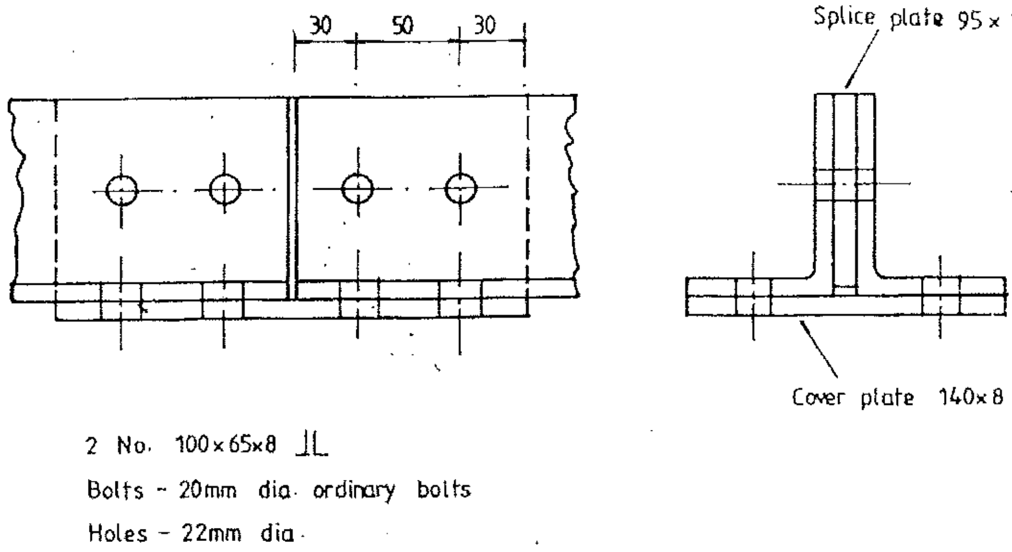


Figure Q6

The connection shown in the figure Q6 is designed with M20 bolts.

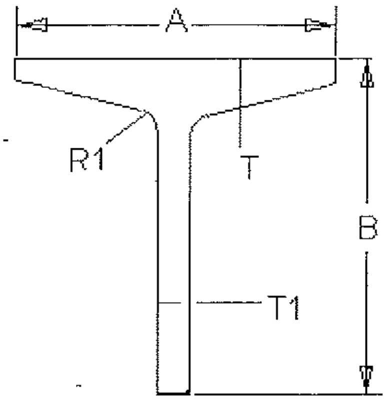
i). Find the capacity of a M20 bolt in single shear connection. (4 Marks)
ii). Find the capacity of a M20 bolt in double shear connection. (4 Marks)
iii). Using the capacities found in i), ii), calculate the capacity of the connection.
(2 Marks)

(b). A simply supported beam with effective span 10 m is used to support the timber (teak) floor of 125 mm in thickness and following details are provided.

Spacing of the beams = 1.5 m
Dead load from the finishers = 1.0 kN/m^2
Density of Teak = 800 kg/m^3
Total imposed load = 2.0 kN/m^2

i). Find the design load applied on the beam. (Take the self-weight of the beam as 25 % of total calculated design load. (4 Marks)

ii). Design the beam selecting a 254 x 343 x 70 T section considering flexural strength.
(6 Marks)



Properties of the 254 x 343 x 70 T section

A = 253.7 mm, B = 341.8 mm, T1 = 12.4 mm, T = 19.0 mm, R1 = 15.2 mm

Area = 89.2 cm^2, Distance to the centroid from the top, C = 8.66 cm,

Second Moment of Area, Ixx = 9926 cm^4, Iyy = 2395 cm^4

Radius of Gyrations - r_x = 10.5 cm, r_y = 5.18 cm

Q7). (a) Explain following terms used in wind load calculation.

i). Design wind speed

ii). Post Disaster Structures

iii). Wind Zones in Sri Lanka (2x 3 = 6 Marks)

(b) The following details shown below is applied to the roof truss of a building. Find the design wind speed can be used in designing the roof truss. (3 Marks)

Details for wind load calculation

Wind Angle = 0^0

Location of the Building = Matara

Building is proposed to use as a Police Station

Total height of the building = 3 m

Terrain Condition 2, Building Class, A

c). i). Derive the formula for Euler buckling load of strut fixed supported at both ends with first principles. (6 Marks)

ii). A strut fixed supported at both ends of effective length 4 m is used as a column and which is loaded only with axial compression load of 100 kN.

Dimension of column - 300 mm x 400 mm

Elastic modulus of column material - 6.9 x 10^8 N/m^2

Compressive strength of column material - 5 N/mm^2

Check whether the member is safe under these conditions (5 Marks)

DATA SHEET

Zone	Basic wind speed V in m/s	
	Post-disaster structures	Normal structures
1	53.5	49.0
2	47.0	42.5
3	38.0	33.5

x 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 19. ALLOWABLE STRESS P_t IN AXIAL TENSION

Form	Grade	Thickness	P_t
		mm	N/mm^2
Sections, bars, plates, wide flats and hot rolled hollow sections	43	≤ 40	170
		over 40 but ≤ 100	155
	50	≤ 63	215
		over 63 but ≤ 100	200
	55	≤ 25	265

TENSILE STRESSES FOR ANGLES, TEES AND CHANNELS

42. *a.* Eccentric connections. When eccentricity of loading occurs in connections of angles and tees in tension, the net areas to be used in computing the mean tensile stress shall be as given by the following rules:

1. *Single angles connected through one leg, channel sections connected through the web and T-sections connected only through the flange.* To the net sectional area of the connected leg, add the sectional area of the unconnected leg multiplied by:

$$\frac{3a_1}{3a_1 + a_2}$$

where a_1 = the net sectional area of the connected leg.
a_2 = the sectional area of the unconnected leg.

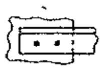
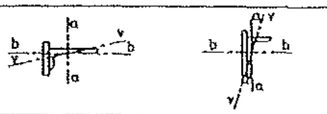
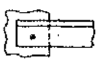
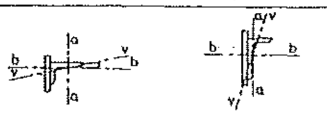
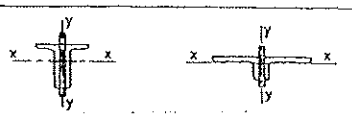
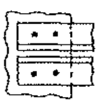
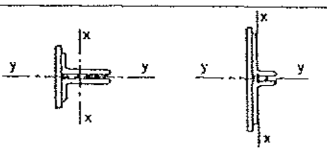
Where lug angles are used, the net sectional area of the whole of the angle member shall be taken.

2. *A pair of angles, channels or T-sections, connected together along their length*, when attached to the same side of a gusset for the equivalent by only one leg of each component:

(i) in contact or separated, by a distance not exceeding the aggregate thickness of the connected parts, with solid packing pieces.

(ii) connected by bolts or welding as specified in Subclauses 51*e* or 54*g* so that the maximum ratio of slenderness of each member between connections is not greater than 80.

TABLE 18. 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 17*a*. 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 30*a*.

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 3 *a*. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm²) 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	174	146	127	113	104	97	94	91	89	88
140	171	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

BS 449: Part2: 1969 Tables & Clause

from BS 449 Table 10: Allowable maximum shear stress p_q

00175

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

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a). Define the term "Null Members of the trusses" (2 Marks)

b). Identify the "Null Members" of given truss in Figure Q1. (2 Marks)

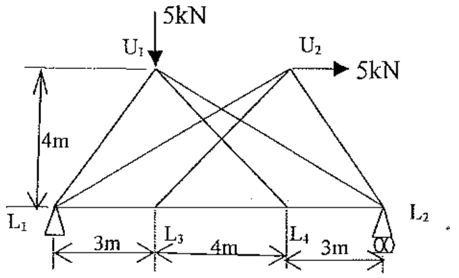


Figure Q1

c). Determine member forces in all the members of the truss given in Figure Q1 by 'Method of joints' or "Graphical method" for loads given. (by indicating the member forces are tension or compression).
Note – Members are connected only at joints L_1, L_2, L_3, L_4, U_1 and U_2.
(10 Marks)

d). Determine the member forces L_1U_2, L_2U_1 and L_2L_4 of the truss given in Q1 using "method of section" (6 Marks)

Q2.) a). State three methods that can be used to find a deflection of the statically determinant trusses. (1.5 Marks)

b). The truss shown in Figure Q2 pin supported at joints L1 and L2.

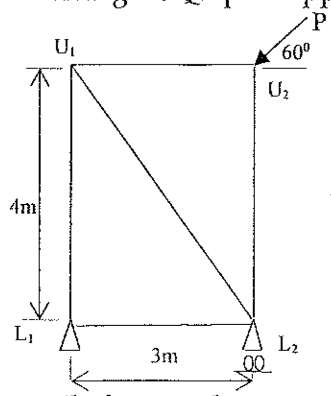


Figure Q2

If allowable tensile force and compressive force are 10 kN and 8 kN respectively find the maximum value for P. (8 Marks)

If allowable tensile force and compressive force are 10 kN and 8 kN respectively find the maximum value for P.
(8 Marks)

c).i). If allowable deflection of the joint U_2 is 5 mm, find the maximum value for P. Take Elastic Modulus of the material is 200 Mpa and all the members are made out with hollow sections of 50 mm x 50 mm with thickness 5 mm.
(3 Marks)

ii). Find the deflection at U_1 in mm if P = 5 kN (7.5 Marks)

Q3) Figure Q3-a shows a continuous beam of ABC

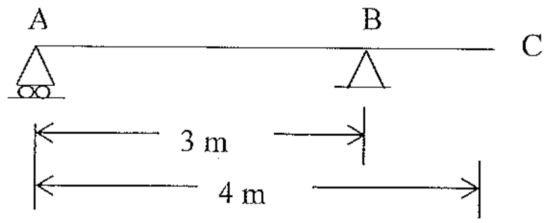


Figure Q3-a

a). Draw Influence lines for followings
   i). Vertical Reaction of A
   ii). Bending moment at mid span of AB (6 Marks)

b). If a uniformly distributed load of 2 kN /m and 2 m in length is moving on the beam, find the maximum Bending Moment of mid span AB. (4 Marks)

c). Three pin arch given in Figure Q3-b is subjected to given loads.

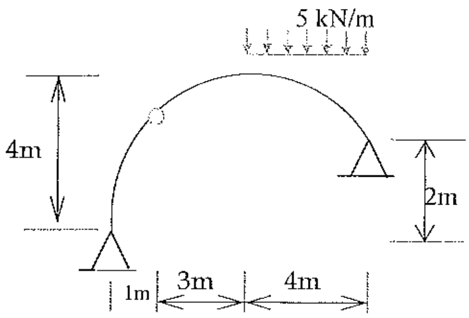


Figure Q3 – b

i). Find a general equation for the arch. (5 Marks)
ii). Find support reactions of the arch. (5 Marks)

Data for Q4 and Q5

Figure Q4-Q5 is shown a joint of a steel truss. Members are connected to a 12 mm thickness gusset plate with M 20 bolts (at least two bolts per each connections). Equal angle steel sections are available with standard sections and it is proposed to use single angle sections and double angle back to back sections. Two members are perpendicular to each other and member A makes 75^0 to the horizontal. 10 kN horizontal load and 5 kN vertical load are applied as shown in the Figure Q4-Q5. The lengths of member A and member B are given as 2 m and 3 m respectively.

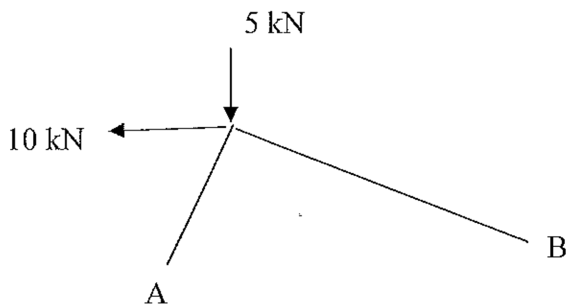


Figure Q4 – Q5

Q4) a). Define the term "eccentricity of the connection" and explain how the eccentricity is allowed in steel design. (2 Marks)

b). i). Find the tension member of the joint with its member force. (2 Marks)
ii). Design the tension member with suitable single angle member. (Minimum Thickness - 8 mm) (6 Marks)
iii). Design the tension member with suitable back to back double angle member. (5 Marks)

c). If additional 5 kN load is applied perpendicular to the tension member at mid span check the suitability of single angle selected in b). ii). (5 marks)

Q5) a). Define the terms i). Buckling of struts, ii). Slenderness ratio, iii). Effect of slenderness ratio to the buckling of struts. (4 Marks)

b). i). Find the compression member of the joint with its member force. (1 Mark)
ii). Design the compression member with suitable single angle member. (Minimum Thickness - 8 mm) (6 Marks)
iii). Design the compression member with suitable back to back double angle Member. (6 Marks)

c). Explain why slenderness ratio should be checked for axes uu, xx and yy for single angle member but only xx and yy axes for double angle members. (3 Marks)

Q6). (a).

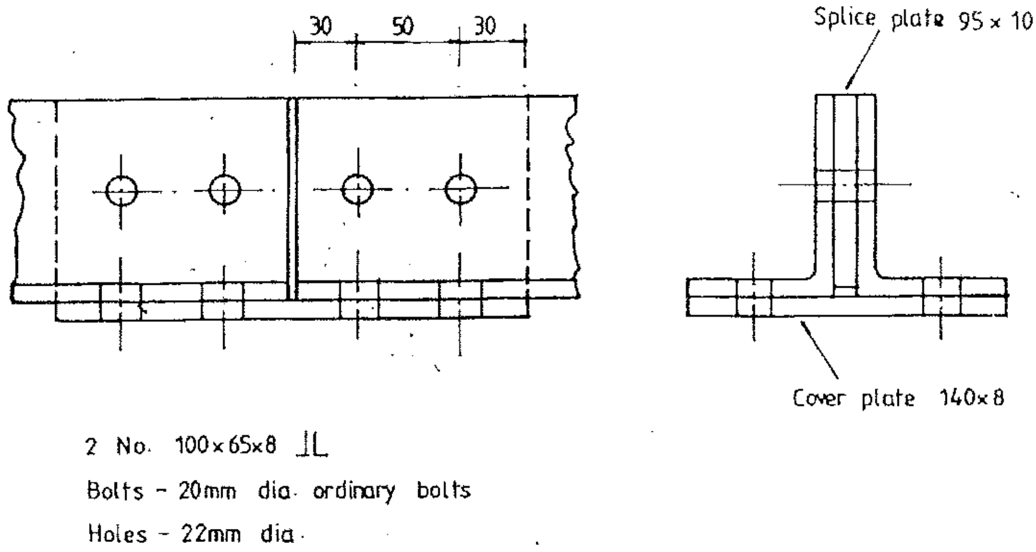


Figure Q6

The connection shown in the figure Q6 is designed with M20 bolts.

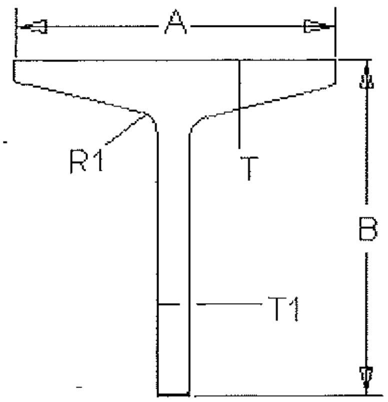
i). Find the capacity of a M20 bolt in single shear connection. (4 Marks)
ii). Find the capacity of a M20 bolt in double shear connection. (4 Marks)
iii). Using the capacities found in i), ii), calculate the capacity of the connection. (2 Marks)

(b). A simply supported beam with effective span 10 m is used to support the timber (teak) floor of 125 mm in thickness and following details are provided.

Spacing of the beams = 1.5 m
Dead load from the finishers = 1.0 kN/m^2
Density of Teak = 800 kg/m^3
Total imposed load = 2.0 kN/m^2

i). Find the design load applied on the beam. (Take the self-weight of the beam as 25 % of total calculated design load. (4 Marks)

ii). Design the beam selecting a 254 x 343 x 70 T section considering flexural strength. (6 Marks)



Properties of the 254 x 343 x 70 T section

A = 253.7 mm, B = 341.8 mm, T1 = 12.4 mm, T = 19.0 mm, R1 = 15.2 mm
Area = 89.2 cm^2, Distance to the centroid from the top, C = 8.66 cm,
Second Moment of Area, Ixx = 9926 cm^4, Iyy = 2395 cm^4
Radius of Gyrations – r_x = 10.5 cm, r_y = 5.18 cm

Q7). (a) Explain following terms used in wind load calculation.

i). Design wind speed
ii). Post Disaster Structures
iii). Wind Zones in Sri Lanka (2x 3 = 6 Marks)

(b) The following details shown below is applied to the roof truss of a building. Find the design wind speed can be used in designing the roof truss. (3 Marks)

<u>Details for wind load calculation</u>

Wind Angle = 0^0
Location of the Building = Matara
Building is proposed to use as a Police Station
Total height of the building = 3 m
Terrain Condition 2, Building Class, A

c). i). Derive the formula for Euler buckling load of strut fixed supported at both ends with first principles. (6 Marks)

ii). A strut fixed supported at both ends of effective length 4 m is used as a column and which is loaded only with axial compression load of 100 kN.
Dimension of column – 300 mm x 400 mm
Elastic modulus of column material – 6.9 x 10^8 N/m^2
Compressive strength of column material – 5 N/mm^2
Check whether the member is safe under these conditions (5 Marks)

DATA SHEET

Zone	Basic wind speed V in m/s	
	Post-disaster structures	Normal structures
1	53.5	49.0
2	47.0	42.5
3	38.0	33.5

x 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 19. ALLOWABLE STRESS P_t IN AXIAL TENSION

Form	Grade	Thickness	P_t
		mm	N/mm^2
Sections, bars, plates, wide flats and hot rolled hollow sections	43	≤ 40	170
		over 40 but ≤ 100	155
	50	≤ 63	215
		over 63 but ≤ 100	200
	55	≤ 25	265

TENSILE STRESSES FOR ANGLES, TEES AND CHANNELS

42. *a.* **Eccentric connections.** When eccentricity of loading occurs in connections of angles and tees in tension, the net areas to be used in computing the mean tensile stress shall be as given by the following rules:

1. *Single angles connected through one leg, channel sections connected through the web and T-sections connected only through the flange.* To the net sectional area of the connected leg, add the sectional area of the unconnected leg multiplied by:

$$\frac{3a_1}{3a_1 + a_2}$$

where a_1 = the net sectional area of the connected leg.
a_2 = the sectional area of the unconnected leg.

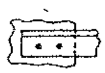
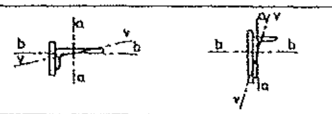
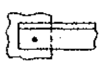
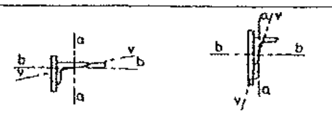
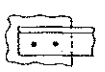
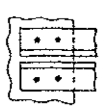
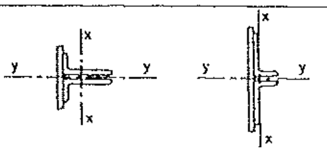
Where lug angles are used, the net sectional area of the whole of the angle member shall be taken.

2. *A pair of angles, channels or T-sections, connected together along their length*, when attached to the same side of a gusset for the equivalent by only one leg of each component:

(i) in contact or separated, by a distance not exceeding the aggregate thickness of the connected parts, with solid packing pieces.

(ii) connected by bolts or welding as specified in Subclauses 51*e* or 54*g* so that the maximum ratio of slenderness of each member between connections is not greater than 80.

TABLE 18. 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.

As altered Dec. 1989

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

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 30*a*.

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 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	174	146	127	113	104	97	94	91	89	88
140	171	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

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/mm²
For 40 < thickness ≤ 100 mm: 115 N/mm²

BS 449 Table 20: Allowable stresses in Rivets and Bolts (N/mm²)

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/mm²)

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

Table 3. Ground roughness, building size and height above ground, factor S_2

H	(1) Open country with no obstructions			(2) Open country with scattered windbreaks			(3) Country with many windbreaks; small towns; outskirts of large cities			(4) Surface with large and frequent obstructions, e.g. city centres		
	Class			Class			Class			Class		
	A	B	C	A	B	C	A	B	C	A	B	C
m												
3 or less	0.83	0.78	0.73	0.72	0.67	0.63	0.64	0.60	0.55	0.56	0.52	0.47
5	0.88	0.83	0.78	0.79	0.74	0.70	0.70	0.65	0.60	0.60	0.55	0.50
10	1.00	0.95	0.90	0.93	0.88	0.83	0.78	0.74	0.69	0.67	0.62	0.58
15	1.03	0.99	0.94	1.00	0.95	0.91	0.88	0.83	0.78	0.74	0.69	0.64
20	1.06	1.01	0.96	1.03	0.98	0.94	0.95	0.90	0.85	0.79	0.75	0.70
30	1.09	1.05	1.00	1.07	1.03	0.98	1.01	0.97	0.92	0.90	0.85	0.79
40	1.12	1.08	1.03	1.10	1.06	1.01	1.05	1.01	0.96	0.97	0.93	0.89
50	1.14	1.10	1.06	1.12	1.08	1.04	1.08	1.04	1.00	1.02	0.98	0.94
60	1.15	1.12	1.08	1.14	1.10	1.06	1.10	1.06	1.02	1.05	1.02	0.98
80	1.18	1.15	1.11	1.17	1.13	1.09	1.13	1.10	1.06	1.10	1.07	1.03
100	1.20	1.17	1.13	1.19	1.16	1.12	1.16	1.12	1.09	1.13	1.10	1.07
120	1.22	1.19	1.15	1.21	1.18	1.14	1.18	1.15	1.11	1.15	1.13	1.10
140	1.24	1.20	1.17	1.22	1.19	1.16	1.20	1.17	1.13	1.17	1.15	1.12
160	1.25	1.22	1.19	1.24	1.21	1.18	1.21	1.18	1.15	1.19	1.17	1.14
180	1.26	1.23	1.20	1.25	1.22	1.19	1.23	1.20	1.17	1.20	1.19	1.16
200	1.27	1.24	1.21	1.26	1.24	1.21	1.24	1.21	1.18	1.22	1.21	1.18