00248

THE OPEN UNIVERSITY OF SRI LANKA
Diploma In Technology (Civil) / Bachelor of Technology – Level 3
CEX 3231 – Structural Analysis & Design 1
Final Examination – 2009/2010
Time Allowed 3 hours

Date: 24ᵗʰ March 2010   Time – 2.00 p.m. – 5.00 p.m.

Answer **five** questions selecting not less than **two** questions from each section.
Please write answers clearly showing any derivations required and stating necessary assumptions.

SECTION A

Q1). i. State three methods that can be used to analyse a Staticaly determinant two dimensional truss.
(3 Marks)

ii. Figure Q1 shows the body diagram of a simply supported plane truss. The roller support at joint U2 is parallel to the member U1M2. The truss is load as shown in Figure Q1.
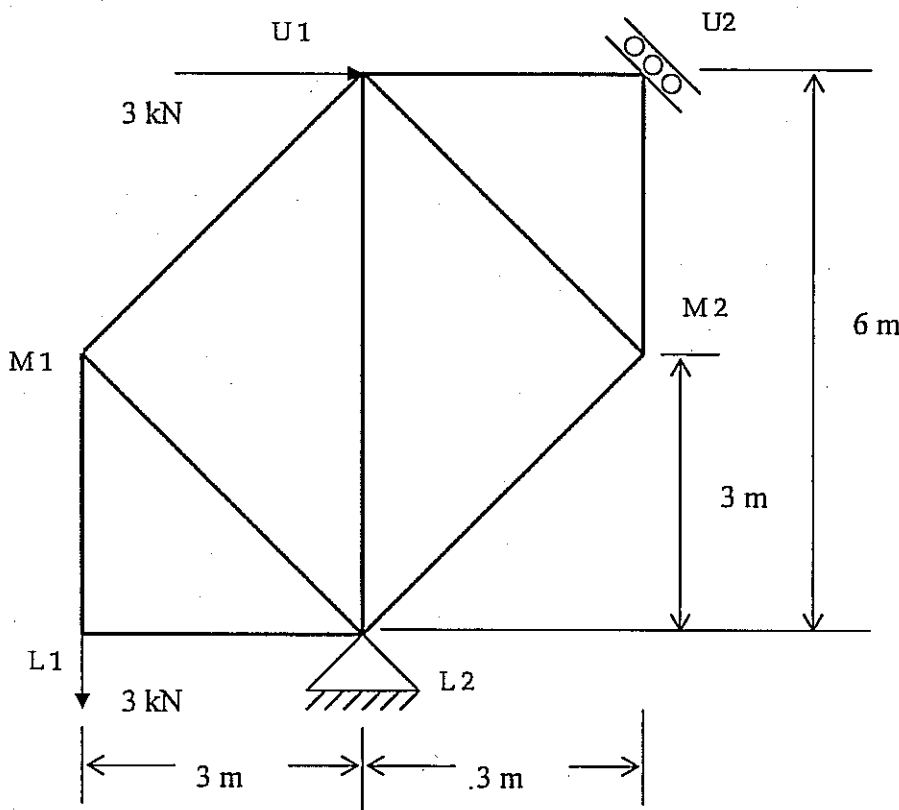
a)   Find member forces of the truss using the method of Joints. Indicate the sign of each member force clearly. (Use the sign convention Tension – positive)

(12 Marks)

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b) Find the member forces in U1M1, M1L2 and U1M2 using the method of Sections.

(5 Marks

Q2). i. Find the displacements of the joint U1 of the truss given in Figure Q1; State the direction of the displacement. (Assume constant AE for all the members)

(12 Marks

ii. Find vertical displacement of joint L1 of the structure if only load applied at L1 is effective.

(8 Marks
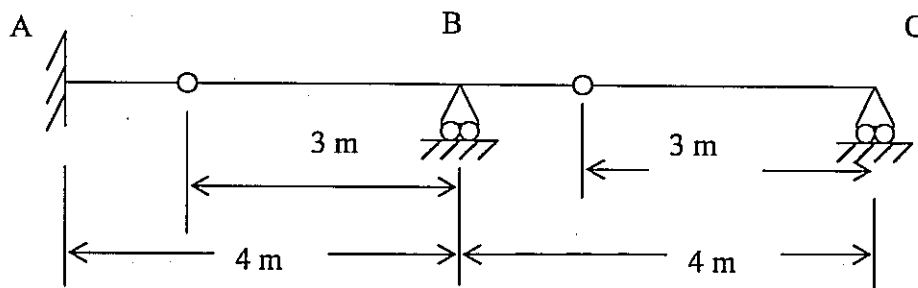
Q3. Figure Q3 shows a continuous beam ADBEC with hinges.

Figure Q3

i. Draw the Influence lines for the following
   a). Reaction at A
   b). Moment at A

(6 Marks

ii. If following loads are moving on the beam, find the maximum Moment at support A when
   a). Two concentrated loads of 5 kN each act at 2 m apart.
   b). A Uniformly distributed load of 2 kN /m and 2 m in length covers the beam.

(8 Marks

iii). Draw BM diagram and shear force diagram for the spans AB, if two unit concentrated loads act at D and E.

(6 Marks

SECTION B

Data for Q4 and Q5

The table Q4 is extracted from the results of a two dimensional truss analyses.

Member Number	Force (kN)	Tension / Compression	Type
1	5	Tension	Web
2	4	Compression	Web
3	8	Compression	Web

4	6	Tension	Web
5	7	Tension	Web
6	9	Compression	Chord
7	4	Compression	Chord
8	11	Tension	Chord
9	0		Chord
10	12.5	Compression	Chord

60 x 60 x 10 EA (Single) angle members are considred for web members of the truss and
2 x 60 x 60 x 10 EA (Double) angles members for chords. M 20 bolts are used for bolted connections.

The properties of a 60 x 60 x 10 equal angle are as follows
Area of Section = 11.1 cm², distance to center of gravity c = 1.85 cm,
Second moment of area
relative to xx-axis , y-y axis = 35.3 cm⁴
Radius of gyration
relative to x-x axis and y-y axis = 1.78 cm and vv-axis = 1.16 cm

Q4. i).Define the term "effective area of the member" used in the design of tension members in steel.

(5 Marks)

ii). Check the suitability of a given angle for the tension web members of a structure.

(8 Marks)

iii). If each web member is subjected to a 5 kNm additional bending moment, check the suitability of the proposed angle.

(7 Marks)

Q 5 i). Discuss the difference between buckling and bending of the structural elements.

(4 Marks)

ii). Design compressive web members of the given structure. Assume that the members are connected with two bolts at each end with a maximum length of the web members as 2m.

(10 marks)

iii). Check the support's strength of a member selected for design in question Q5. (ii).

(6 Marks)

The allowable strengths are:

the allowable stress in bolts in clearance holes, in shear = 80 N/mm²
the allowable stress in bolts in clearance holes, in bearing = 250 N/mm²
the allowable bearing stresses on connected parts = 250 N/mm²
the end distance of 22 mm diameter holes = 32 mm

Q 6). Figure Q6 shows the body diagram of a simply supported steel beam.

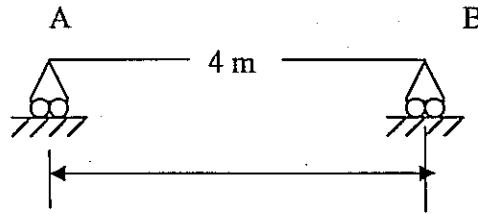A   B

Figure Q6

The beam supports the concrete slab of 125 mm in thickness and following details are provided.

Spacing of the beams = 2.5 m
Density of Concrete = 24 kN/m³
Imposed load from the people = 1.5 kN/m²
Imposed load from the furniture = 0.5 kN/m²
Dead load from the finishers = 1.0 kN/m²
Allow 15% of total load for self weight of the beam

i). Find the design load applied on the beam.

(5 Marks)

ii). If a structural Tee 419 x 457 x194 mm is selected for this beam, check the suitability of the beam considering the flexural strengths.

(10 Marks)

From the tabulated properties 419 x 457 x194
    Area of the section = 104.5 cm²
    Plastic Modulus Z_{xx} = 2190 cm³
    Depth of Section, D = 460.2 mm
    Flange Thickness, T = 36.6 mm
    Radius of gyration, r_x = 13.4 cm and r_y = 9.58cm

iii). Find the maximum shear stress applied on the beam.

(5 Marks)

Q7). i). Show that Euler Buckling load of pin ended strut is given by.

$$P = P_{cr} = \frac{EI}{L^2} \pi^2$$

(7 Marks)

ii). State five assumptions used in derivation of Euler Buckling load

(5 Marks)

iii). Sketch the "Leeward slope" and "Windward Slope" of a roof truss.

(3 Marks)

iv). Briefly explain the method of finding basic wind speed for a building situated in Batticaloa area.

(5 marks)

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TABLE 19. ALLOWABLE STRESS P_t IN AXIAL TENSION

Form	Grade	Thickness	P_t
		mm	N/mm^2
Sections, bars, plates,	43	≤ 40	170
wide flats and hot		over 40 but $\leq$ 100	155
rolled hollow sections	50	≤ 63	215
		over 63 but $\leq$ 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 51e or 54g so that the maximum ratio of slenderness of each member between connections is not greater than 80.

To the net sectional area of the connect part, add the sectional area of the unconnected part multiplied by:

$$\frac{5a_1}{5a_1 + a_2}$$

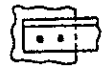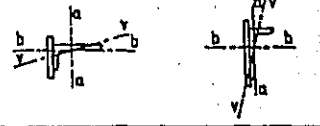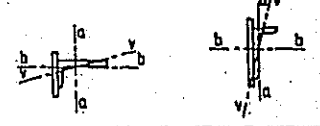where a_1 = the net sectional area of the connected part.
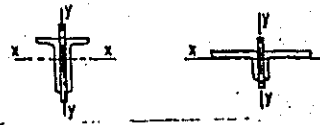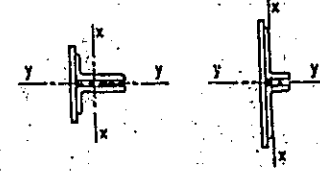
a_2 = the sectional area of the unconnected part.

Where the components are widely spaced, this rule does not apply, and the member shall be specially designed.

b. **Double angles, tees or channels** placed back-to-back and connected to each side of a gusset or to each side of part of a rolled section. For computing the mean tensile stress the net sectional area of the pair shall be taken, provided the members are connected together along their length as specified in Subclause 51 e or 54g.

NOTE. The area of the leg of an angle shall be taken as the product of the thickness by the length from the outer corner minus half the thickness, and the area of the leg of a tee as the product of the thickness by the depth minus the thickness of the table.

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 17a   ALLOWABLE STRESS p_c ON GROSS SECTION FOR AXIAL COMPRESSION

As altered
Dec. 1989

p_c (N/mm²) for grade 43 steel

l/r	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 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.	43	≤ 40 / >40 but ≤ 100	180 / 165
Compound beams composed of rolled sections plated, with thickness of plate.	50	≤ 63 / >63 but ≤ 100	230 / 215
Double channel sections forming a symmetrical I-section which acts as an integral unit.	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 3a. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm²) FOR CASE A OF CLAUSE 19a(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