

2705/302

2709/302

2710/302

### STRUCTURES III

June/July 2018

Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

### DIPLOMA IN BUILDING TECHNOLOGY DIPLOMA IN ARCHITECTURE

#### MODULE III

#### STRUCTURES III

3 hours

#### INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

- answer booklet;
- calculator;
- drawing instruments.

Answer any FIVE of the following EIGHT questions.

All questions carry equal marks.

Maximum marks for each part of a question are indicated.

Candidates should answer the questions in English.

This paper consists of 12 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1. Using moment distribution method, analyse the beam loaded as shown in figure 1 and hence sketch the shear force and bending moment diagrams indicating the values at all critical points. (20 marks)

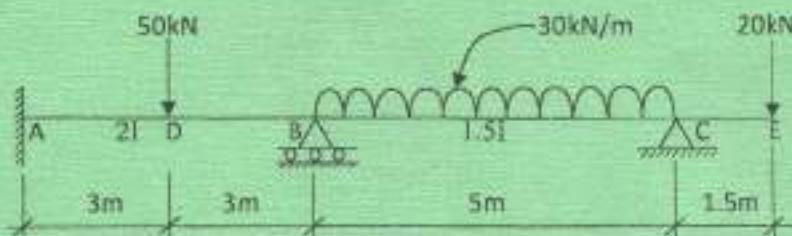


Figure 1

2. Using the three moments theorem, analyse the beam, shown in figure 2 and hence sketch the shear force diagram indicating all critical values. (20 marks)

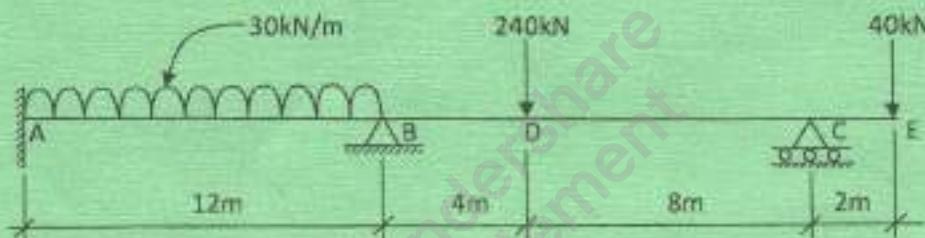


Figure 2

3. (a) Sketch the influence line diagrams for the following when the unit load crosses the beam as shown in figure 3:

- (i) reaction at A;
- (ii) reaction at B;
- (iii) bending moment at D.

(11 1/2 marks)

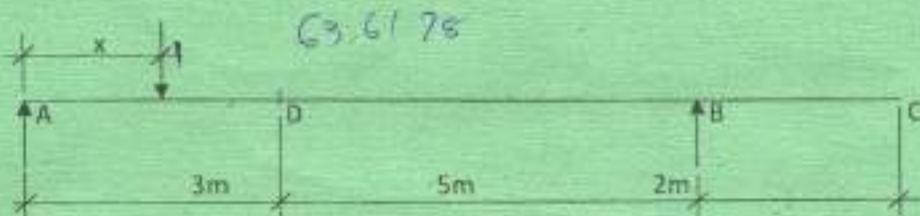


Figure 3

- (b) Determine the maximum bending moment at D when a uniformly distributed load of 50kN/m and 6m long crosses the beam shown in figure 3 from A to C.

(8 ½ marks)

4. Using moment distribution method, analyse the frame shown in figure 4 and hence Sketch the bending moment diagram indicating the values at all the critical points.

(20 marks)

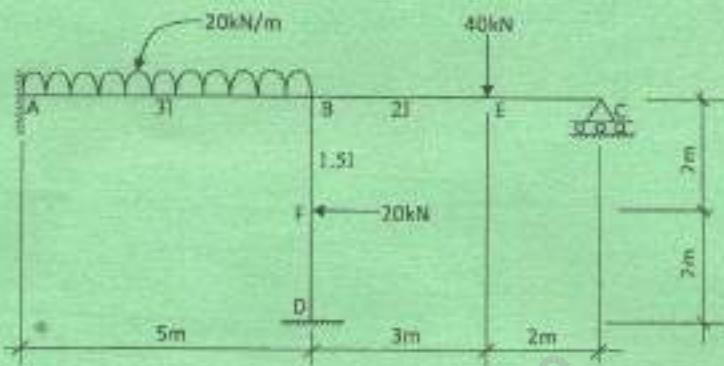


Figure 4

5. (a) Define the following terms with respect to structural timber:

- (i) dry stress;
- (ii) grade stress;
- (iii) glued laminated member;
- (iv) strength class.

(4 marks)

- (b) Describe mechanical stress grading of timber. (4 marks)

- (c) A timber column of strength class 3 (SC3) consists of a 100 mm square section which is restrained at both ends in position but not in direction. Assuming the actual length is 3.9 m, determine the maximum long term load the column can carry.

Using the information in tables 1 to 3.

(12 marks)

6. Figure 5 shows the layout plan of a suspended reinforced concrete slab supported on universal beams (UB). Assuming the beams are fully laterally restrained select a suitable UB section in grade 43 steel for beam marked 'X' to satisfy bending, shear and deflection. Use the the following information:

- density of reinforced concrete =  $2,400 \text{ Kg/m}^3$
- live load =  $3 \text{ kN/m}^2$
- partitions =  $1.5 \text{ kN/m}^2$
- finishes =  $0.8 \text{ kN/m}^2$
- $E = 205 \text{ kN/m}^2$
- permissible deflection =  $\frac{1}{360}$  span. (20 marks)

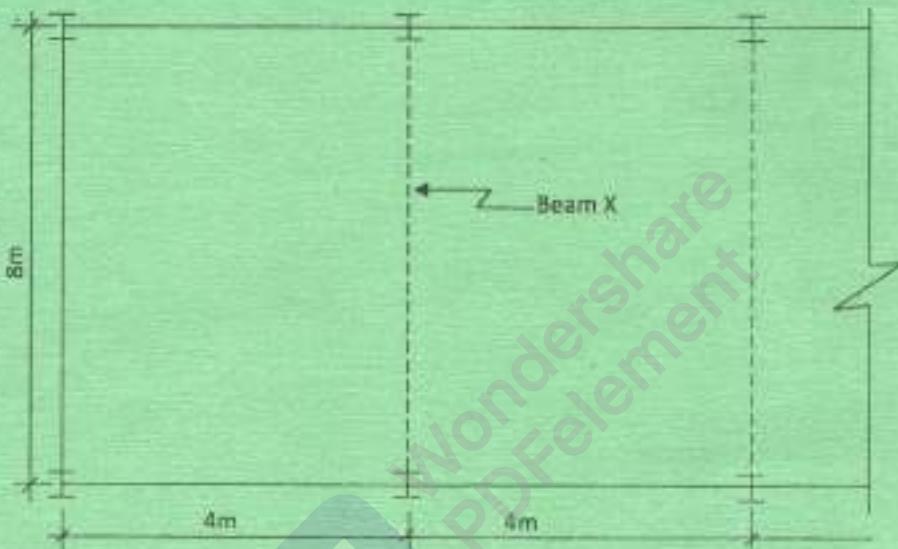


Figure 5

7. Timber floor joists of effective length 4 m are spaced at 450 mm centres and have bearing of 100 mm at the supports. Using the following information, design the joists for bending and hence check for shear, deflection and bearing;

- Timber strength class SC3
- Medium term loading duration.
- Loading:
  - T & G boarding and ceiling =  $0.24 \text{ kN/m}^2$
  - Joists =  $0.14 \text{ kN/m}^2$
  - Imposed load =  $1.5 \text{ kN/m}^2$
  - Available timber sizes
    - 225 x 50 mm
    - 200 x 50 mm
    - 175 x 50 mm
  - Use information provided in tables. (20 marks)

8. (a) State two examples for each of the following limit states:

- (i) ultimate;
  - (ii) serviceability.
- (2 marks)

(b) With the aid of sketches, describe the following methods of design of steel structures:

- (i) simple design;
  - (ii) rigid design.
- (6 marks)

(c) Determine the compressive resistance for a 305 x 305 x 118 Kg/m UC section if it is encased in concrete of compressive strength 20 N/mm<sup>2</sup> as per BS 5950.

(12 marks)

Table 1

Duration of loading	Value of $K_3$
Long term (e.g. dead + permanent imposed)	1.00
Medium term (e.g. dead + snow, dead + temporary imposed)	1.25
Short term (e.g. dead + imposed + wind, dead + imposed + snow + wind)	1.50
Very short term (e.g. dead + imposed + wind)	1.75

Table 2: Depth factor,  $K_7$ 

1.  $K_7 = 1.17$  for solid beams having a depth  $< 72\text{mm}$
2.  $K_7 = \left(300/h\right)^{0.11}$  for solid beams  
with  $72\text{mm} < h < 300\text{mm}$
3.  $K_7 = 0.81\left(h^2 + 92300\right)/\left(h^2 + 56800\right)$  for solid beams  
with  $h > 300\text{mm}$

Table 3: Grade stresses, modulus of elasticity and density for strength classes SC1-9 for the dry exposure condition

Strength Class	Bending parallel to grain (N/mm <sup>2</sup> )	Tension parallel to grain (N/mm <sup>2</sup> )	Compression parallel to grain (N/mm <sup>2</sup> )	Compression perpendicular to grain* (N/mm <sup>2</sup> )	Shear parallel to grain (N/mm <sup>2</sup> )	Modulus of elasticity (E <sub>parallel</sub> ) (N/mm <sup>2</sup> )	Modulus of elasticity (E <sub>perpendicular</sub> ) (kgm <sup>-1</sup> )	Approximate Density
SC1	2.8	2.2	3.5	2.1	1.2	0.46	6800	4500
SC2	4.1	2.5	5.3	2.1	1.6	0.66	8000	5000
SC3	5.3	3.2	6.8	2.2	1.7	0.67	8800	5800
SC4	7.5	4.5	7.9	2.4	1.9	0.71	9900	6600
SC5	10.0	6.0	8.7	2.8	2.4	1.00	10700	7100
SC6	12.5	7.5	12.5	3.8	2.8	1.50	14100	11800
SC7	15.0	9.0	14.5	4.4	3.3	1.75	16200	13600
SC8	17.5	10.5	16.5	5.2	3.9	2.00	18700	15600
SC9	20.5	12.3	19.5	6.1	4.6	2.25	21600	18000

Table 4  
Reinforcement-bar areas ( $\text{mm}^2$ ) per metre width for various bar spacings

Bar Diameter (mm)	Bar spacing (mm)									
	75	100	125	150	175	200	225	250	275	300
6	377	283	226	189	162	142	126	113	103	94
8	671	503	402	335	287	252	223	201	183	168
10	1047	785	628	523	449	393	349	314	286	262
12	1508	1131	905	754	646	566	503	452	411	377
16	2681	2011	1608	1340	1149	1005	894	804	731	670
20	4189	3142	2513	2094	1795	1571	1396	1257	1142	1047
25	6545	4909	3927	3272	2805	2454	2182	1963	1785	1636
32	-	8042	6434	5362	4596	4021	3574	3217	2925	2681
40	-	-	10050	8378	7181	6283	5585	5027	4570	4189

Areas of group of reinforcement bars ( $\text{mm}^2$ )

Bar Diameter (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28	57	85	113	141	170	198	226	254	283
8	50	101	151	201	251	302	352	402	452	503
10	79	157	236	314	393	471	550	628	707	785
12	113	226	339	452	565	679	792	905	1017	1131
16	201	402	603	804	1005	1206	1407	1608	1809	2011
20	314	628	942	1257	1571	1885	2199	2513	2827	3142
25	491	982	1473	1963	2454	2945	3436	3927	4418	4909
32	804	1608	2412	3216	4021	4825	5629	6433	7237	8042
40	1256	2513	3769	5026	6283	7539	8796	10050	11310	12570



Table 5

<i>Design grade</i>	<i>Thickness (mm), less than or equal to</i>	<i>Sections, plates and hollow sections, <math>p_y</math> (<math>N \text{ mm}^{-2}</math>)</i>
43	16	275
	40	265
	63	255
	80	245
50	100	235
	16	155
	40	345
	63	335
55	80	325
	100	315
	16	450
	25	430
	40	
	63	400

Design in structural steelwork to BS 5950

Table 6: Limiting width to thickness ratios (elements which exceed these limits are to be taken as class 4, slender cross-sections)

<i>Type of element (all rolled sections)</i>	<i>Class of section</i>		
	<i>(1) Plastic</i>	<i>(2) Compact</i>	<i>(3) Semi-compact</i>
Outstand element of compression flange	$\frac{b}{T} \leq 9.5 \epsilon$	$\frac{b}{T} \leq 9.5 \epsilon$	$\frac{b}{T} \leq 15 \epsilon$
Web with neutral axis at mid-depth	$\frac{d}{t} \leq 79 \epsilon$	$\frac{d}{t} \leq 98 \epsilon$	$\frac{d}{t} \leq 120 \epsilon$
Web subject to compression throughout	$\frac{d}{t} \leq 39 \epsilon$	$\frac{d}{t} \leq 39 \epsilon$	$\frac{d}{t} \leq 39 \epsilon$

Note.  $\epsilon = (275/p_y)^{1/2}$  (4.4)

Table 7 : Compressive strength, pc (N mm<sup>-2</sup>) for struts

$\frac{P_s}{P_c}$	225	245	255	265	275	$\lambda$	225	245	255	265	275
15	225	245	255	265	275	96	133	140	143	146	148
20	224	243	253	263	272	98	130	137	139	142	145
25	220	239	248	258	267	100	127	133	136	138	141
30	216	234	243	253	262	102	124	130	132	135	137
35	211	229	238	247	256	104	122	127	129	131	133
40	207	224	233	241	250	106	119	124	126	128	130
42	205	222	231	239	248	108	116	121	123	125	126
44	203	220	228	237	245	110	113	118	120	121	123
46	201	218	226	234	242	112	111	115	117	118	120
48	199	215	223	231	239	114	108	112	114	115	117
50	197	213	221	229	237	116	105	109	111	112	114
52	195	210	218	226	234	118	103	106	108	109	111
54	192	208	215	223	230	120	100	104	105	107	108
56	190	205	213	220	227	122	98	101	103	104	105
58	188	202	210	217	224	124	96	99	100	101	102
60	185	200	207	214	221	126	94	96	97	99	100
62	183	197	204	210	217	128	91	94	95	96	97
64	180	194	200	207	213	130	89	92	93	94	95
66	178	191	197	203	210	135	84	86	87	88	89
68	175	188	194	200	206	140	79	81	82	83	84
70	171	185	190	196	203	145	75	77	78	78	79
72	169	181	187	193	198	150	71	72	73	74	74
74	167	179	183	189	194	155	67	69	69	70	70
76	164	175	180	185	190	160	64	65	66	66	66
78	161	171	176	181	186	165	60	61	62	63	63
80	158	168	172	177	181	170	57	58	59	59	60
82	155	164	169	173	177	175	55	56	56	56	57
84	152	161	165	169	173	180	52	53	53	54	54
86	149	157	161	165	169	185	49	50	51	51	51
88	146	154	158	161	165	190	47	48	48	48	49
90	143	150	154	157	161	195	45	46	46	46	47
92	139	147	150	153	156	200	43	44	44	44	44
94	136	143	147	150	152						

Table 8: Compressive strength,  $p_c$  (N mm $^{-2}$ ) for struts (Table 27(c), BS 5950)

$\lambda$	$p_c$					$\lambda$	$p_c$				
	225	245	255	265	275		225	245	255	265	275
15	225	245	255	265	275	96	133	140	143	146	148
20	224	243	253	263	272	98	130	137	139	142	145
25	220	239	248	258	267	100	127	133	136	138	141
30	216	234	243	253	262	102	124	130	132	135	137
35	211	229	238	247	256	104	122	127	129	131	133
40	207	224	233	241	250	106	119	124	126	128	130
42	205	222	231	239	248	108	116	121	123	125	126
44	203	220	228	237	245	110	113	118	120	121	123
46	201	218	226	234	242	112	111	115	117	118	120
48	199	215	223	231	239	114	108	112	114	115	117
50	197	213	221	229	237	116	105	109	111	112	114
52	195	210	218	226	234	118	103	106	108	109	111
54	192	208	215	223	230	120	100	104	105	107	108
56	190	205	213	220	227	122	98	101	103	104	105
58	188	202	210	217	224	124	96	99	100	101	102
60	185	200	207	214	221	126	94	96	97	99	100
62	183	197	204	210	217	128	91	94	95	96	97
64	180	194	200	207	213	130	89	92	93	94	95
66	178	191	197	203	210	135	84	86	87	88	89
68	175	168	194	200	206	140	79	81	82	83	84
70	172	185	190	196	202	145	75	77	78	78	79
72	169	181	187	193	198	150	71	73	73	74	74
74	167	175	183	189	194	155	67	69	69	70	70
76	164	173	180	183	190	160	64	65	66	66	66
78	161	171	176	181	196	165	60	61	62	63	63
80	158	168	172	177	181	170	57	58	59	59	60
82	155	161	169	173	177	175	55	56	56	56	57
84	152	161	165	169	173	180	52	53	53	54	54
86	149	157	161	165	169	185	49	50	51	51	51
88	146	154	158	161	165	190	47	48	48	48	49
90	143	150	154	157	161	195	45	46	46	46	47
92	139	147	150	153	156	200	43	44	44	44	44
94	136	143	147	150	152						





## UNIVERSAL COLUMNS

Parallel Flanges

### DIMENSIONS AND PROPERTIES

## UNIVERSAL COLUMNS

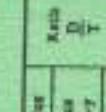
Parallel Flanges

### DIMENSIONS AND PROPERTIES

10

Serial Size	Height per mm	Width of Section D	Depth of Section B	Thickness Web T	Thickness Flange F	Root Radius R	Area of Section A	Depth between Flanges		Area of Girder	Axis X-X	Axis Y-Y	Axis Z-Z	Radius of Curvature at the Center of Bend	
								in²	in						
238 x 408	9.24	474.1	424.1	47.6	77.0	15.2	790.1	603.1	230.1	237021	200215	821855	18.0	11302	
	9.61	485.7	418.3	45.0	87.6	15.2	790.1	701.0	230.1	1631118	181331	67925	10.3	9864	
	4.67	426.8	412.4	36.9	98.0	15.2	790.1	695.3	230.1	1487065	129159	55410	12.1	2851	
	3.63	418.1	407.0	30.8	49.2	15.2	790.1	600.9	230.1	1224576	107867	48010	10.4	2293	
*		4.40	409.4	403.0	38.5	42.8	790.1	422.7	230.1	98598	87943	29714	15.0	80327	
		2.87	382.3	388.0	21.8	26.6	790.1	386.0	230.1	79170	69134	31038	10.3	2324	
		2.95	381.0	385.0	18.5	20.2	790.1	230.1	230.2				10.2	1840	
												4193	1870	10.9	
														12.0	
<b>Column Core</b>	<b>4.77</b>	<b>427.0</b>	<b>428.4</b>	<b>48.0</b>	<b>82.2</b>	<b>15.2</b>	<b>230.1</b>	<b>607.1</b>	<b>230.1</b>	<b>172381</b>	<b>1522226</b>	<b>88937</b>	<b>16.8</b>	<b>10.8</b>	
<b>236 x 388</b>	<b>2.02</b>	<b>374.3</b>	<b>374.4</b>	<b>16.8</b>	<b>27.0</b>	<b>15.2</b>	<b>230.1</b>	<b>287.5</b>	<b>230.1</b>	<b>63207</b>	<b>57020</b>	<b>23621</b>	<b>15.7</b>	<b>8.87</b>	
	1.77	368.2	372.1	14.5	23.8	15.2	230.1	225.7	230.1	57153	49798	20470	18.9	3.53	
	1.53	362.0	370.2	12.8	20.7	15.2	230.1	195.2	230.1	48835	43230	17470	19.8	1110	
	1.28	358.6	368.2	10.7	17.5	15.2	230.1	194.2	230.1	40248	35040	14835	15.8	943.8	
														19.5	
														20.3	
<b>202 x 308</b>	<b>2.83</b>	<b>392.2</b>	<b>321.8</b>	<b>28.9</b>	<b>46.1</b>	<b>15.2</b>	<b>240.0</b>	<b>200.4</b>	<b>240.0</b>	<b>78777</b>	<b>71837</b>	<b>24037</b>	<b>14.8</b>	<b>8.87</b>	
		240.0	262.8	21.0	27.7	15.2	230.1	230.1	230.1	64177	69235	20230	14.5	1252	
		1.83	238.8	314.1	19.2	31.4	15.2	240.0	230.2	60632	49323	16220	14.2	12.8	
		1.58	322.2	316.0	18.7	26.0	15.2	240.0	201.2	58140	57768	13204	14.2	10.5	
		1.37	310.3	308.7	13.3	21.7	15.2	240.0	174.8	50828	50314	10873	13.7	2888	
		1.18	314.4	308.6	11.8	18.7	15.2	240.0	168.8	27601	26478	90046	13.8	8014	
		0.97	307.4	304.8	16.9	15.2	240.0	123.3	240.0	22722	25448	7598	13.8	567.0	
														15.8	
														20.6	
<b>234 x 384</b>	<b>1.67</b>	<b>289.1</b>	<b>284.5</b>	<b>19.3</b>	<b>31.7</b>	<b>12.7</b>	<b>200.2</b>	<b>211.4</b>	<b>200.2</b>	<b>2384</b>	<b>23914</b>	<b>21171</b>	<b>11.8</b>	<b>8.41</b>	
	1.22	278.4	281.0	18.6	25.1	12.7	200.2	181.7	200.2	2384	20390	746.4	11.6	8.04	
	1.07	286.4	285.2	13.0	20.5	12.7	200.2	176.8	200.2	17510	11860	8901	11.3	10.8	
	0.83	280.4	281.9	10.5	17.3	12.7	200.2	114.0	200.2	14307	13976	48649	11.2	5.87	
		0.73	284.0	284.0	8.8	14.2	12.7	200.2	92.3	11380	15287	3913	11.1	6.57	
														15.1	
<b>203 x 303</b>	<b>1.64</b>	<b>289.1</b>	<b>284.5</b>	<b>19.3</b>	<b>31.7</b>	<b>12.7</b>	<b>200.2</b>	<b>211.4</b>	<b>200.2</b>	<b>203</b>	<b>203</b>	<b>9482</b>	<b>8224</b>	<b>3227</b>	
												7841	5759	8.16	8.32
												6086	5287	2041	10.8
												52162	46559	1170	6.62
												45644	40216	1529	6.45
												3513	1131	5.11	5.45
														10.6	
														15.1	
														20.6	

**THIS IS THE LAST PRINTED PAGE.**



Parallel Flanges

Dimensions and Properties

Note: One hole is deducted from each flange width 200 mm wide (total size) and two holes from each flange 300 mm (one each side), in calculating the Net Moment of Inertia about x-x.