[ENG01]

THE UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (Hons) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2021/2022

ADVANCED STRUCTURAL ANALYSIS & DESIGN

MODULE NO. CIE6001

Date: Monday 16th May 2022 **Time: 14:00 – 17:00**

INSTRUCTIONS TO CANDIDATES:

There are THREE questions
Answer ALL questions.

Marks for each question are shown in brackets.

For Question 3, use the Multiple choice answer sheet in the Appendices (page 11). Include it in your answer booklet.

Total 100 marks for the paper.

Extracts from EC3 to be used with Question 2 are included with this paper.

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Question 1.

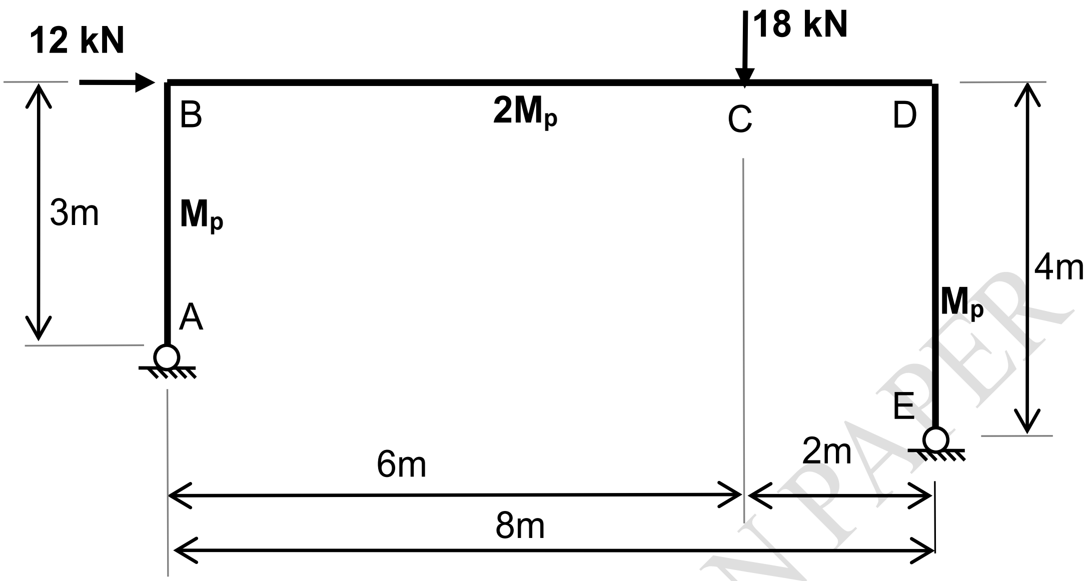

Figure Q1

Figure Q1 shows a rigid-jointed frame ABCDE pinned to supports at A and at E. The plastic moment of the two columns is $\mathbf{M_p}$ and for the beam is $\mathbf{2M_p}$

The frame carries a horizontal point load of 12 kN at B, and a vertical point load of 18 kN at C.

a. Find the value of $\mathbf{M_P}$ which corresponds to a combined collapse mechanism with plastic hinges at **C** and at **D.** **(5 marks)**

b. Draw the bending moment diagram for the mechanism found in (a) and show that it is not the critical collapse mechanism. **(10 marks)**

c. Choose another collapse mechanism with one plastic hinge at **D** and one plastic hinge at the position of maximum bending moment found in part (b). Determine the corresponding value of **Mp** and draw the bending moment diagram. **(15 marks)**

Total 30 marks

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Question 2

a) List three factors that influence the value of the imperfection factor **α** used in the EC3 method to find the buckling capacity of a slender column. **(5 marks)**

b) A column is laterally restrained every 4 m against buckling about the minor axis (z-z) but has no intermediate restraints against buckling about the major axis (y-y) as shown in Figure Q2. The column is considered to be pinned in both directions.
The column is subjected to a design load N_{Ed} **= 4350** kN.
The size of the column is UKC 305x305x97 with a steel grade S355.

Determine the buckling resistance of the column about both axes using EC3 method. Comment on the results.
(25 marks)

Total 30 Marks

UKC 305x305x97
A= 123 cm^2
I_y = 22200 cm^4
I_z = 7310 cm^4
h = 307.9 mm
b = 305.3 mm
t_w = 9.9 mm
t_f = 15.4 mm
E = 210 kN/mm^2
f_y = 355 N/mm^2

Partial safety factor $\gamma_{M1} = 1$
Cross-section is Class 2

$$N_{cr} = \frac{\pi^2 EI}{l_{cr}^2}$$

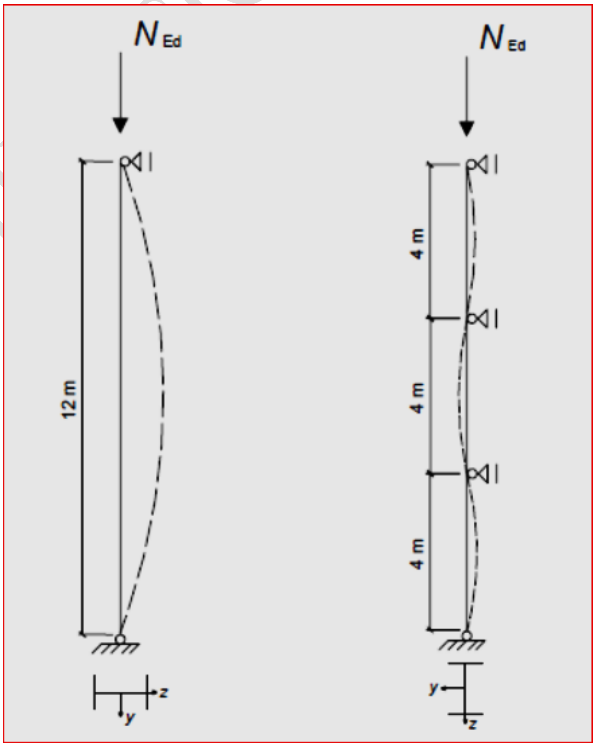

Figure Q2

Extracts from EC3 to be used with Question 2 are included in Appendix A.

Question 3

PART A – COMPOSITE SECTION

Figure Q3 shows the section of a composite beam made of steel beam and concrete slab. The beam is simply supported over a span of 9m that carries a uniformly distributed load of 30 kN/m (including the self-weight).

The steel elastic modulus, E_s, is 210,000 N/mm^2 and the concrete elastic modulus, E_c, is 21,000 N/mm^2. The steel beam has a cross-sectional area of 85.5 cm^2 and a moment of inertia I_{xx}=19643 cm^4

(a) Transform the composite section to an equivalent steel beam. Find the position of neutral axis from the bottom of the section and I value of the transformed beam. **(11 marks)**

(b) Calculate the maximum stress in the steel, maximum stress in the concrete and the maximum deflection of the composite beam.

(11 marks)

(c) If the steel beam carried the load without composite action, find the maximum stress and maximum deflection of the steel beam.

(6 marks)

The central deflection of a simply supported beam carrying a uniformly distributed load is given by: $\delta = 5wL^4/384EI$

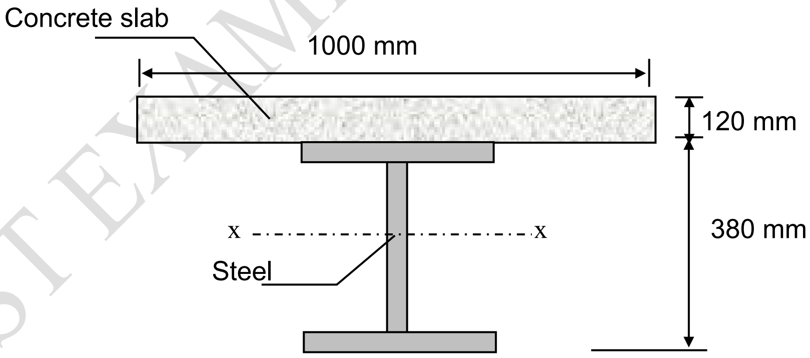

Figure Q3

Question 3 continues on next page…..

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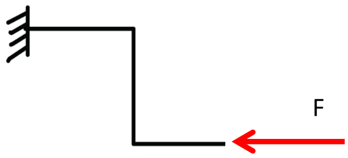
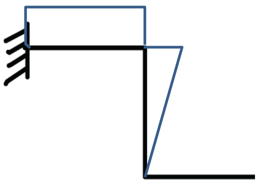
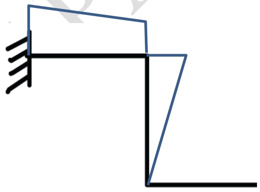
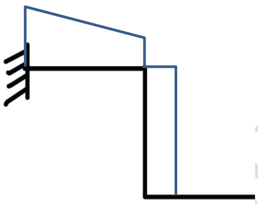
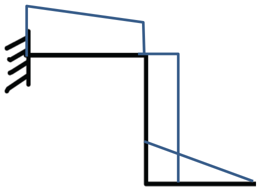
Question 3 continued…

<u>PART B</u> - Understanding structural behaviour

In answering Question **3 PART B** please tear out and use the multiple-choice marking sheet in **Appendix B**

Q3B-1	Choose the bending moment diagram (BMD) that matches the structure shown. (3 marks)		
 			
A		**B**	
C		**D**	

Question 3 Part B continues over the page….

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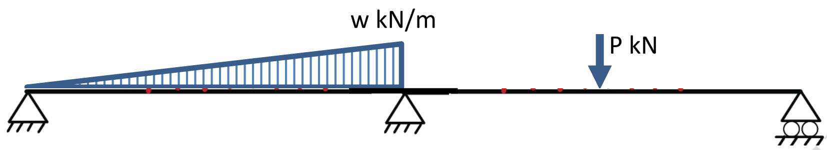
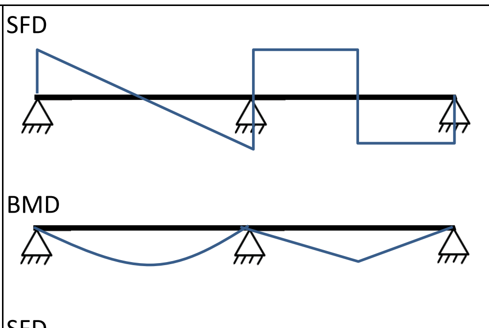
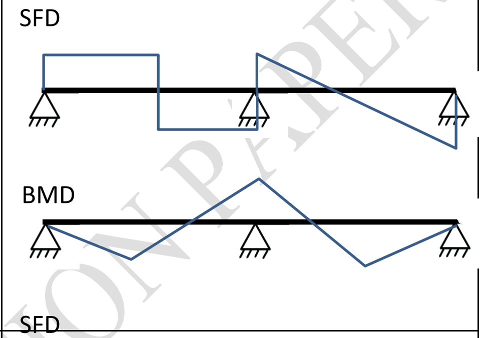
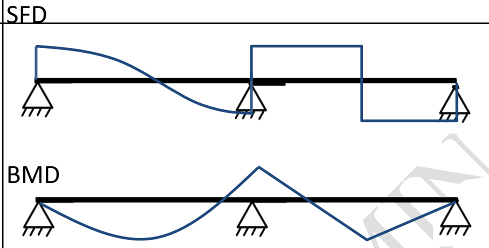
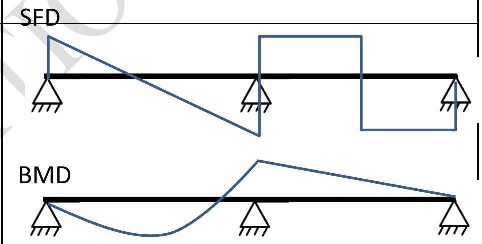
Question 3 Part B continued….

Q3B-2	Choose the shear force diagram (SFD) and bending moment diagram (BMD) that match the structure shown. (3 marks)
	
A	
B	
C	
D	

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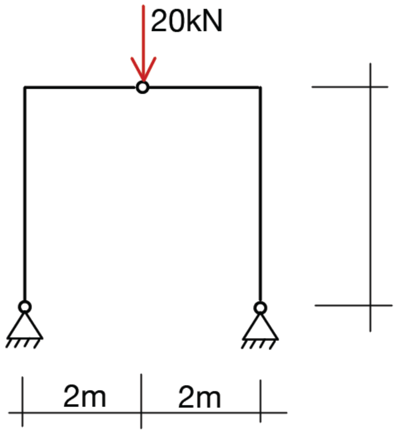
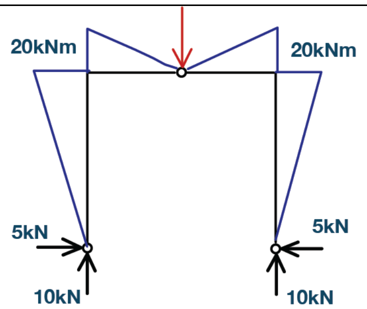
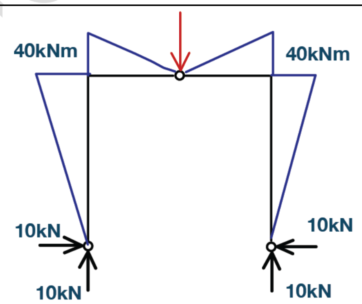
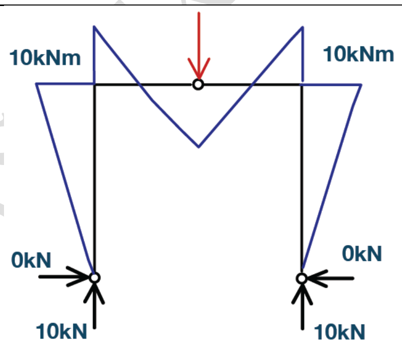
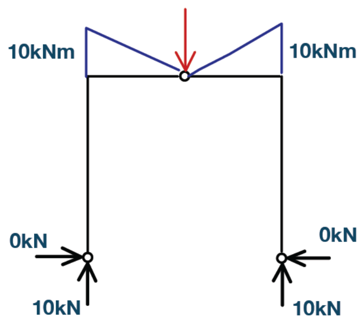
Question 3 Part B continued….

<u>PART B</u> - Understanding structural behaviour

Q3B-3	Choose the bending moment diagram (BMD) that matches the structure shown. Consider the values of the bending moments given in the answer choices. (3 marks)		
			
A		**B**	
C		**D**	

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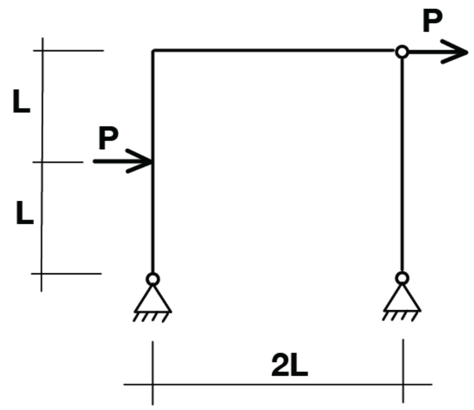
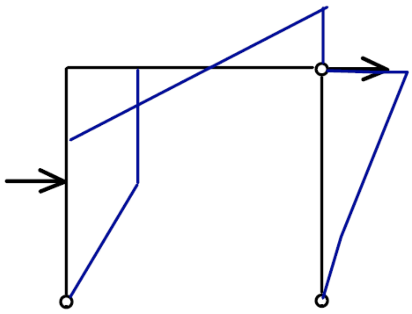
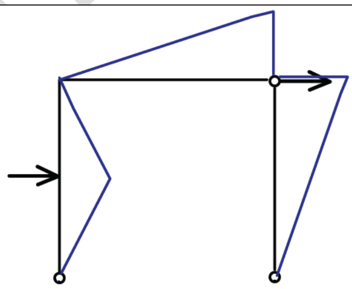
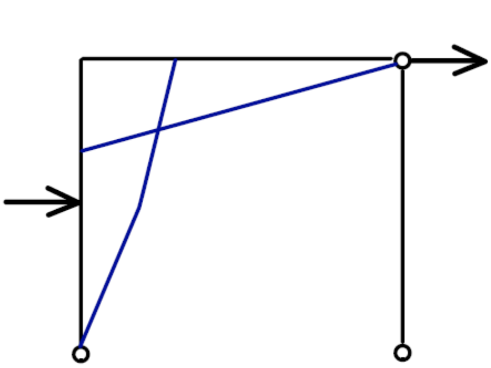
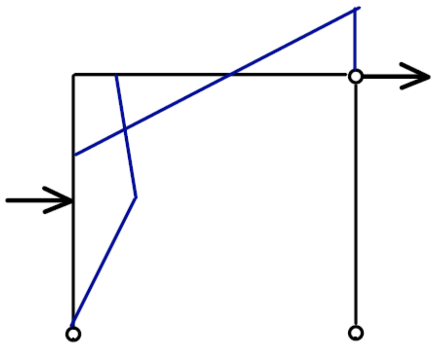
Question 3 Part B continued….

Q3B-4	Choose the bending moment diagram (BMD) that matches the structure shown (3 marks)		
			
A		**B**	
C		**D**	

(Total 40 marks)

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APPENDIX A – Extract from EC3 to be used with Question 2

6.3 Buckling resistance of members

6.3.1 Uniform members in compression

6.3.1.1 Buckling resistance

(1) A compression member shall be verified against buckling as follows:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0 \quad (6.46)$$

where

N_{Ed} is the design value of the compression force
$N_{b,Rd}$ is the design buckling resistance of the compression member.

(3) The design buckling resistance of a compression member should be taken as:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad \text{for Class 1, 2 and 3 cross-sections} \quad (6.47)$$

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad \text{for Class 4 cross-sections} \quad (6.48)$$

where χ is the reduction factor for the relevant buckling mode.

NOTE For determining the buckling resistance of members with tapered sections along the member or for non-uniform distribution of the compression force second-order analysis according to 5.3.4(2) may be performed. For out-of-plane buckling see also 6.3.4.

(4) In determining A and A_{eff} holes for fasteners at the column ends need not to be taken into account.

6.3.1.2 Buckling curves

(1) For axial compression in members the value of χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ should be determined from the relevant buckling curve according to:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \leq 1,0 \quad (6.49)$$

where $\Phi = 0,5\left[1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2\right]$

$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$ for Class 1, 2 and 3 cross-sections

$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$ for Class 4 cross-sections

α is an imperfection factor
N_{cr} is the elastic critical force for the relevant buckling mode based on the gross cross sectional properties.

(2) The imperfection factor α corresponding to the appropriate buckling curve should be obtained from Table 6.1 and Table 6.2.

Table 6.1 — Imperfection factors for buckling curves

Buckling curve	a_0	a	b	c	d
Imperfection factor α	0,13	0,21	0,34	0,49	0,76

(3) Values of the reduction factor χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ may be obtained from Figure 6.4.

(4) For slenderness $\bar{\lambda} \leq 0,2$ or for $\frac{N_{Ed}}{N_{cr}} \leq 0,04$ the buckling effects may be ignored and only cross-sectional checks apply.

Appendix A continues over the page….
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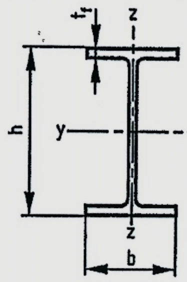
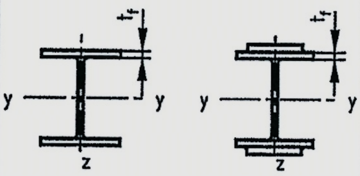
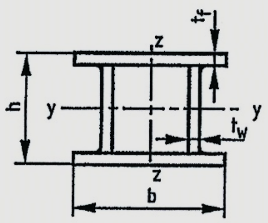
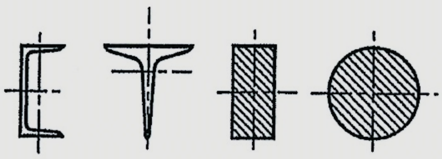
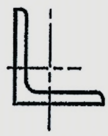
APPENDIX A continued….

Extract from EC3 to be used with Question 2

Table 6.2 — Selection of buckling curve for a cross-section

Cross section		Limits		Buckling about axis	Buckling curve: S 235, S 275, S 355, S 420	Buckling curve: S 460
Rolled sections		h/b > 1,2	$t_f \leq 40$ mm	y – y z – z	a b	a_0 a_0
		h/b > 1,2	40 mm < $t_f \leq 100$	y – y z – z	b c	a a
		h/b ≤ 1,2	$t_f \leq 100$ mm	y – y z – z	b c	a a
		h/b ≤ 1,2	$t_f > 100$ mm	y – y z – z	d d	c c
Welded I sections		$t_f \leq 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c d
Hollow sections		hot finished		any	a	a_0
		cold formed		any	c	c
Welded box sections		generally (except as below)		any	b	b
		thick welds: $a > 0{,}5t_f$ $b/t_f < 30$ $h/t_w < 30$		any	c	c
U, T and solid sections				any	c	c
L sections				any	b	b

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APPENDIX B

Multiple choice answer sheet to be used with Question 3 PART B

Please tear out this page of the exam paper and enclose it with your exam script.

Student ID:_____________

	Student number:					
Questions	**Circle** the correct answers					**Marks (please leave this column blank)**
Q3B - 1	**A**	**B**	**C**	**D**	**3**	
Q3B – 2	**A**	**B**	**C**	**D**	**3**	
Q3B – 3	**A**	**B**	**C**	**D**	**3**	
Q3B – 4	**A**	**B**	**C**	**D**	**3**	
				TOTAL	**12**	

It is essential that your answers are clear, as ambiguous answers and crossing out may make it impossible to award marks for parts of this question.

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