UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: August 2018

Module Number: CE3205 **Module Name: Structural Analysis I**

[Three Hours]

[Answer **all question**, each question carries twelve marks]

Q1 a) Fig. Q1 (a) shows a propped cantilever beam with moment M_{AB} applied at the pined end. Applied moment M_{AB} courses rotation θ_{AB} at the pinned end and moment M_{BA} at the remote fixed end. Using either virtual work or energy theorem calculate and show that the rotation stiffness of the beam $M_{AB}/\theta_{AB} = 4EI/L$ and the moment transferred to remote fixed end M_{BA} is $M_{AB}/2$.

[5 Marks]

b) Beam having two cantilever parts are supported at points A, B, C and D as shown in Fig. Q1 (b). Draw the bending moment diagram and shear force diagram of the beam using principals of moment distribution. Assume that the beam section is uniform throughout the length and that it has constant stiffness EI.

[7 Marks]

Q2 a) State two theories involved with the formulation of Three Moment Theorem (TMT) in your own words. Use sketches (if any) required to clarify your explanations.

[4 Marks]

b) A straight elastic beam ABC of uniform cross section with constant flexural rigidity $EI = 4.2\times10^5$ kNm^2 is used as a floating bridge deck across a waterway. Deck is supported on three cylindrical floats at A, B and C, which are equally spaced (distance "l=4m") along the section as shown in Fig Q2. The maximum load expected on the beam deck is considered as a uniformly distributed load of $w = 4$ kN/m. It is expected that supports will settle based on the magnitude of the reaction and the buoyancy force (uplift force acting on the floats due to water pressure) causing additional moment on the deck. Ignore the self-weight of the beam and the buoys. Assume that the bridge deck is straight before the application of the imposed load. Buoys used as support were cylinders having 1.4 m diameter.

(i) Based on the conditions described above, using the Three Moment Theorem calculate the minimum height of the cylinders required to ensure that the no part of the bridge will be in submerged conditions at the time of the application of full load. Uplift force is equal to $v\rho g$. $v = \pi D^2/4.\delta$, $\rho_{water} = 1000 kg/m^3$, $g = 9.81\ ms^{-2}$. [Equation of TMT with usual notations is given as follows]

$$\frac{M_1 l_1}{E_1 I_1} + 2M_2\left(\frac{l_1}{E_1 I_1} + \frac{l_2}{E_2 I_2}\right) + \frac{M_3 l_2}{E_2 I_2} = 6\left[\left(\frac{\delta_1 - \delta_2}{l_1} + \frac{\delta_3 - \delta_2}{l_2}\right) - \left(\frac{A_1 a_1}{E_1 I_1 l_1} + \frac{A_2 a_2}{E_2 I_2 l_2}\right)\right]$$

[Hint: In order to satisfy the condition of non-submergence height of the buoys should be greater than δ_1 , δ_2 and δ_3]

[9 Marks]

(ii) Draw the bending moment and shear force diagram of the beam ABC under the maximum applied load.

[3 Marks]

Q3 Fig. Q3(a) shows an idealized portal frame structure ABC constructed to be used as a car park. The column of the portal frame is fixed at the ground while free end of the beam kept sliding on top of an existing structure. The only load on the structure is considered to be the roof load applied on the beam. The rotational stiffness EI of the column and beam were 4×10^4 kN/m² and 8×10^4 kN/m² respectively.

(a) Considering the uniformly distributed load on the beam from the roof as 10 kN/m (*w*=10 *kN/m*), calculate the rotation at the joints B and C using slope deflection relationship.

[6 Marks]

(b) Based on the rotations calculated in part (a), determine the moment at joints A, B and C and hence complete bending moment and shear force diagrams of the frame ABC.

[3 Marks]

(c) In an event that the column is pined to the ground (Fig. Q3(c)), explain how the calculation of the above moment would be different.

[3 Marks]

Q4 Fig. Q4 shows a wall frame subjected to horizontal load. Based on the conditions of the connection all joints ABCD of the frame structure is considered pinned. All wall members (i.e. members AB, BC, CD, AC and BD) are subjected to temperature rise of 20°C during day time at service compared to the time of its fabrication. The member DB, the last fabricated element, is initially reported to be 3mm longer than its expected dimensions at the time of fabrication. All members of the frame are fabricated using steel having cross section area 750 mm² and the Young's modulus of 205 kN/mm². Applied horizontal load at B is 100 kN. Coefficient of thermal expansion of steel = $10 \times 10^{-6}\ {}^{0}C^{-1}$.

a) Assuming appropriate virtual force system calculate the member forces of the pined jointed frame ABCD with due consideration to the lack of fit, temperature rise, and applied load.

[8 Marks]

b) Calculate the horizontal deformation of the truss frame at B due to above loading.

[4 Marks]

Q5 a) Express Castigliano's theorem of strain energy and complimentary strain energy in your own wards.

[2 Marks]

b) Fig Q5 shows one of the main frame of an advertising board. Frame is made with hollow circular steel tube with Young's modulus E and second moment of area I (rotational stiffness EI). Wind force applied on the structure is idealized as a horizontal point load of magnitude P applied at point D. In addition, beam BC is applied with a uniformly distributed load of intensity *w* kN/m as shown in Fig. Q5

(i) Express the bending moment at a general point of the beam elements AB, BC and BD and calculate the total strain energy of the system due to bending.

[3 Marks]

(ii) Based on the total strain energy of the system, calculate the joint reaction and complete the bending moment diagram of the frame ABCD.

[4 Marks]

c) Based on the knowledge of strain energy of the system compute the lateral displacement of the point D.

[3 Marks]

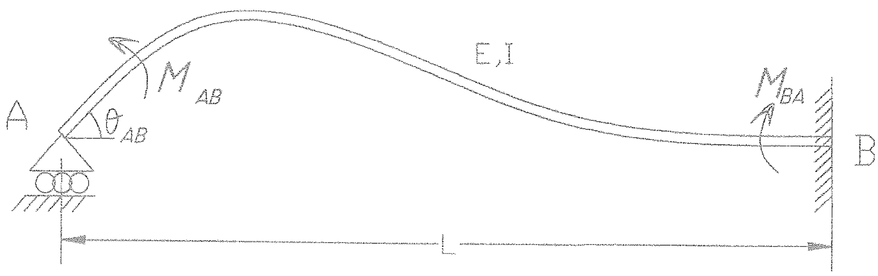

Fig. Q1(a)

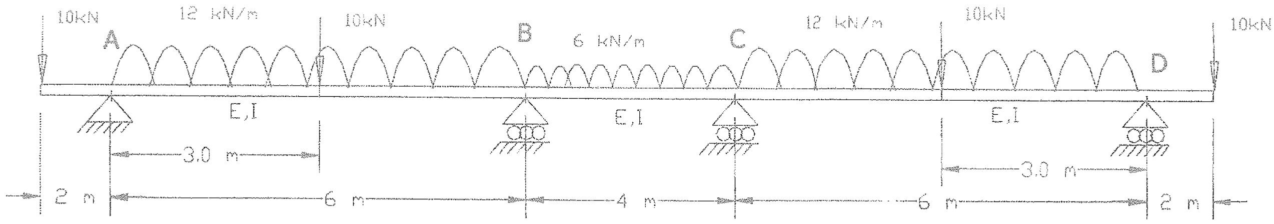

Fig. Q1(b)

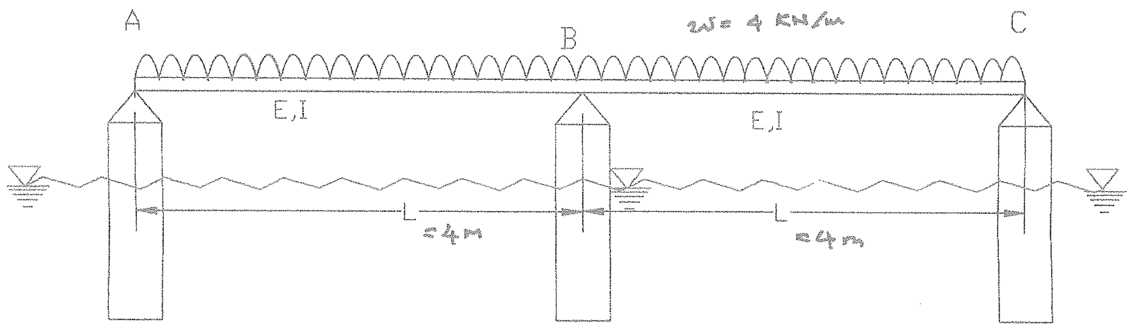

Fig. Q2

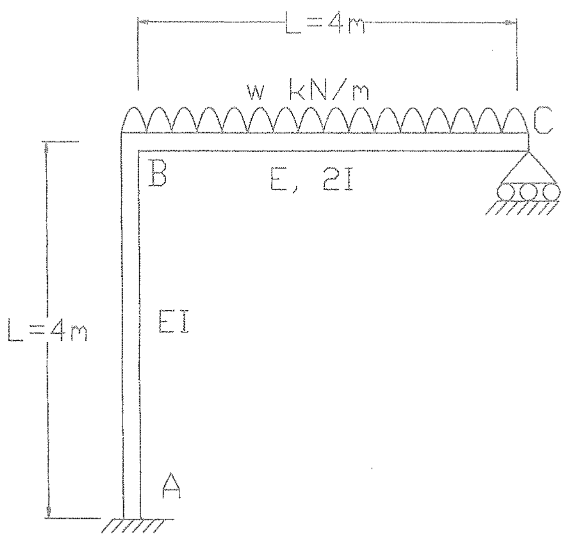

Fig. Q3 (a)

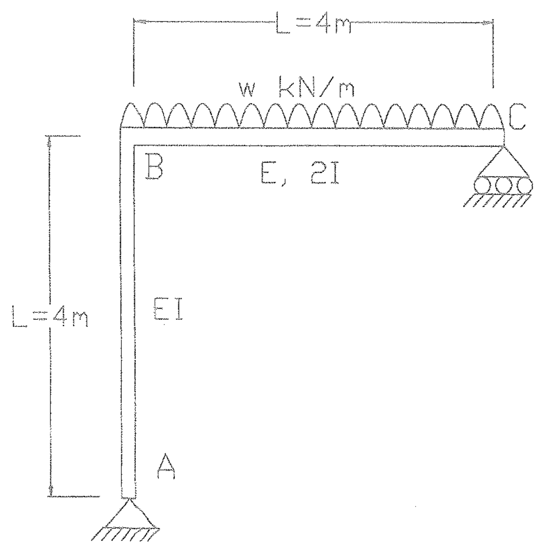

Fig Q3(c)

Fig. Q3

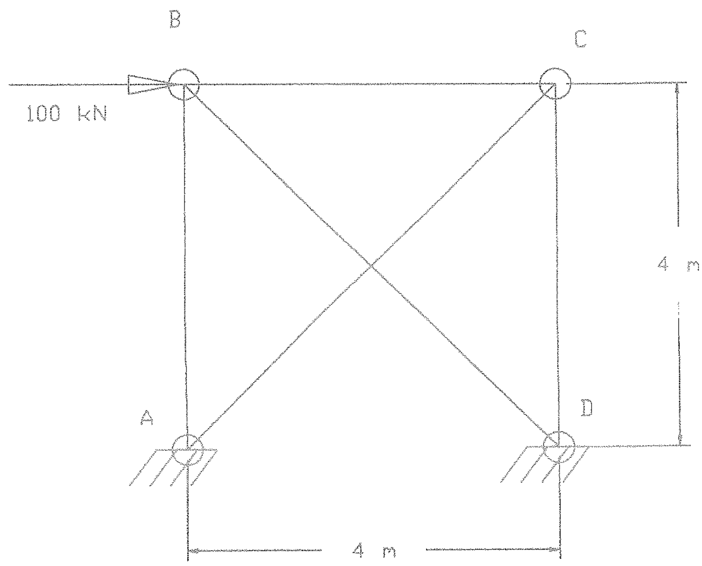

Fig. Q4

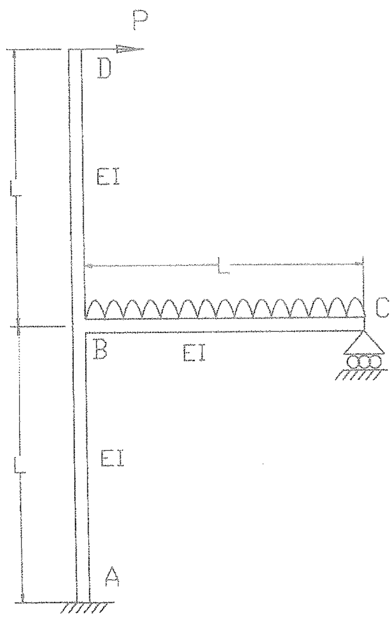

Fig. Q5