THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Diploma In Technology (Civil) - Level 4

CEX 4231 - Structural Analysis and Design II

FINAL EXAMINATION - 2006

Time Allowed: Three (03) Hours

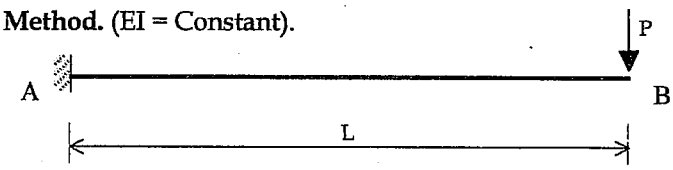
Date: 2007 - 03 – 04 (Sunday) Time: 0930 - 1230 hrs.

Answer Five (05) questions with at least Two (02) questions from each section.
Necessary extracts from BS 8110 will be provided separately.

Section A - Structural Analysis

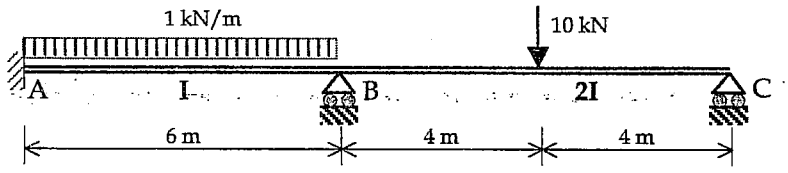
Q1.

a.) Determine the deflection at the end B of the loaded cantilever beam shown below, using **Moment-Area Method.** (EI = Constant).



(05 marks)

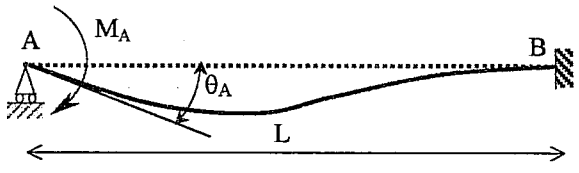
b.) During loading, the support B of the continuous beam ABC shown below, sinks by 1.0 cm. Analyse the beam using the **theorem of Three Moments** and sketch the Bending Moment Diagram ($E=2x10^5$ N/mm^2, $I=1.5x10^7$ cm^4) (**I** values are indicated near the members).



(15 marks)

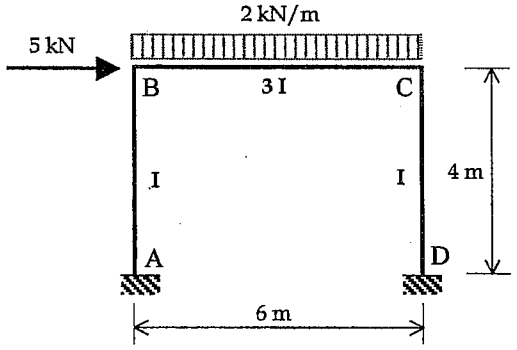
Q2.

a.) The support A of the beam shown below has rotated by an angle θ_A. Using the **Moment Area Method** show that the moments induced at the two supports will be $M_A = 4EI\theta_A/L$ & $M_B = -2EI\theta_A/L$, where EI is the flexural rigidity of the beam.



(05 marks)

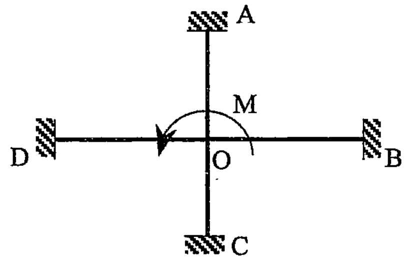
b.) Analyse the frame shown below using **Slope Deflection Equations** and sketch the bending moment diagram (**I** values are indicated near the members).



(15 marks)

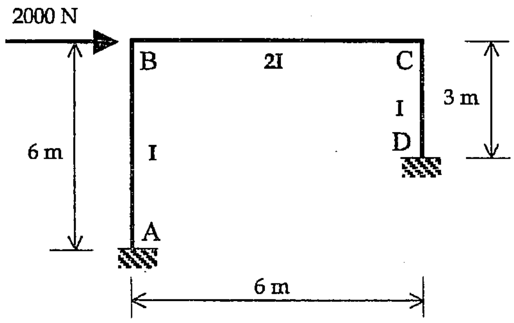
Q3.

a.) Members OA, OB, OC & OD are rigidly connected at O. A moment M is applied at joint O. Show that the moment induced in member OA is given by;
$M_{OA} = K_{OA} M/(K_{OA}+K_{OB}+K_{OC}+K_{OD})$
where, K_{OA}, K_{OB}, K_{OC} & K_{OD} are stiffnesses of OA, OB, OC & OD



(05 marks)

b.) Analyse the frame shown below using Moment Distribution Method and sketch the bending moment diagram (I values are indicated near the members).



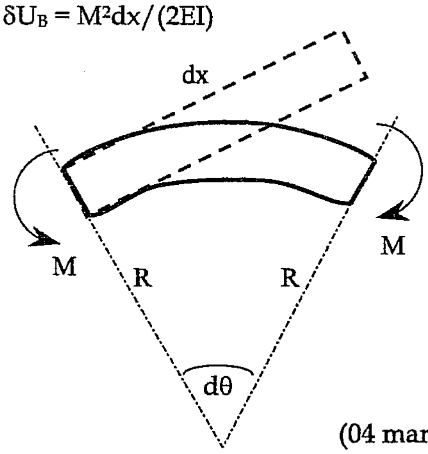
(15 marks)

Q4.

a.) State Castigliano's two theorems on strain energy.

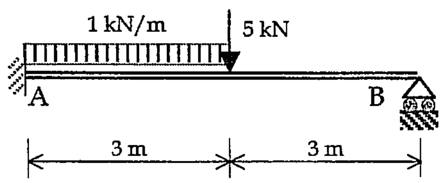
(04 marks)

b.) A small element of a bar, length dx, is subjected to a constant bending moment M causing it to bend into an arc of radius R subtending an angle dθ at the centre. Show that the strain energy resulting from bending is given by $\delta U_B = M^2dx/(2EI)$



(04 marks)

c.) The propped cantilever beam AB is loaded as shown below. Using Castigliano's Second Theorem, determine vertical reaction at support B (EI = Constant).

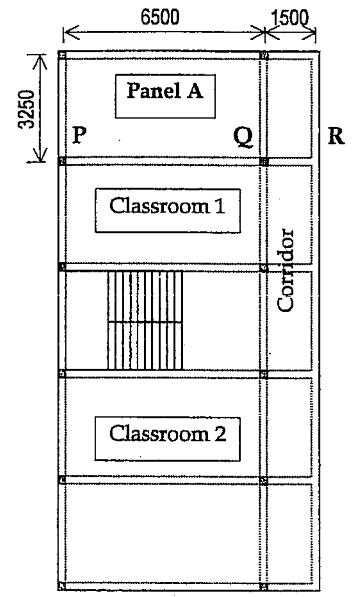


(12 marks)

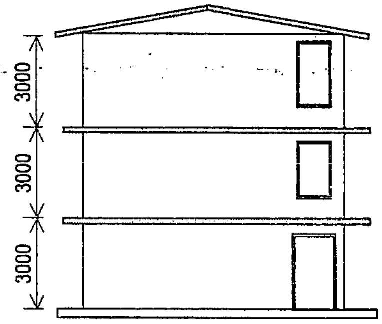
Section B - Design of Structures

All designs are to be done according to the recommendations of the Standard BS 8110.
For questions Q5 & Q6 use the data and parameters pertaining to the following structure.

Ministry of Education requires type plans for classroom buildings for national schools throughout the country. For efficient utilization of land area, three storied buildings were decided by the Chief Designs Engineer in charge of this project.



Plan of an upper floor slab



Side Elevation

For durability and structural integrity under diverse conditions prevalent in different parts of the country, the Engineer decided on reinforced concrete framed structure concept to be used for construction with peripheral walls made of masonry block work. An upper floor structural plan and the side elevation of a proposed six-classroom building are given here.

General Notes:

* Dotted lines indicate beams & grids are spaces equally.
* Marked intersection points of beams are supported on 225 mm square columns
* Transverse beams (PQR) are of 450 x 300 mm & longitudinal beams are 300 x 225 cross-section
* Corridor is cantilevering from classrooms
* Slabs are to be 125 thick
* Roof is entirely supported by the 12 columns.
* Block work walls are 100 thick

All Dimensions are in 'mm'

Technical Specifications:

Concrete grade	- 30
Grade of Steel fy HT steel	- 460 N/mm²
MS	- 250 N/mm²
Unit weight of concrete	- 24 kN/m³
Unit weight of Masonry	- 18 kN/m³
Dead load by roof	- 1.0 kN/m²
Weight of finishes on slab	- 1.0 kN/m²
Imposed load on slab	- 2.5 kN/m²
Nominal cover for reinforcement	- 20 mm

Q5.

Using the given data, design the **'Panel A'** of the upper floor slab, assuming all loads to be uniformly distributed. Follow the steps below for the design.

i.) Evaluate the characteristic (dead load & imposed load due to normal loading) and the design load on the panel as area loads. (02 marks)

ii.) Identify the spanning condition of the slab and calculate appropriate mid span and over the support moments. (You may use the factors from table in the handout) (05 marks)

iii.) Design reinforcement to resist bending at mid spans and over supports for the slab panel. (05 marks)

iv.) Check for deflection of the slab panel and if necessary, only propose suitable modifications. (04 marks)

v.) Sketch the reinforcement on a plan and one cross section of the slab panel using the standard method of detailing (not necessary to indicate curtailment lengths) (04 marks)

Q6.

Using data pertaining to the structure given above, design the beam **PQR** (there are no walls on the beam), along following steps assuming the effective beam section to be rectangular;

i.) Evaluate the characteristic dead and imposed loads transferred on to the beam and calculate the maximum design load. (You may assume that loads on the beam are uniformly distributed and neglect the point load by half-wall at the end of the cantilever R)
(04 marks)

ii.) Calculate the design bending moments and shear forces at critical sections of the beam segment QR and sketch the Bending moment and Shear force diagrams.
(04 marks)

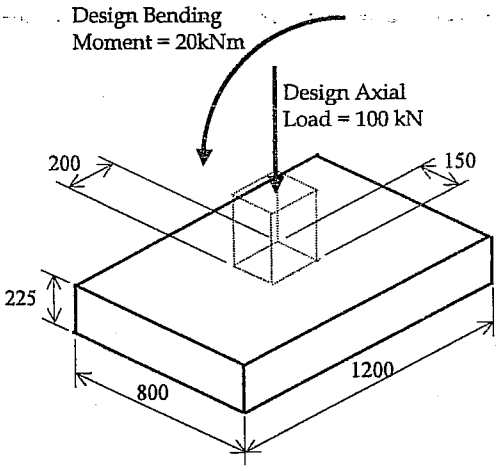
iii.) Design the reinforcement to resist bending at the critical sections of the beam. (You may assume 20 mm dia. tor steel tensile reinforcement & 6 mm dia. MS shear stirrups.)
(04 marks)

iv.) Check for shear at critical sections of the beam and provide shear reinforcement if necessary. (You may assume two or four legged 6 mm MS shear stirrups.)
(04 marks)

v.) Check for deflection of the beam based on conditions at the mid span and the end of the cantilever. Propose modifications if this check fails.
(04 marks)

Q7.

Isometric view of a rectangular pad footing supporting a column of a portal frame is given below. Through analysis of the frame, the design axial load (excluding the self weight of the footing) and bending moment about the major axis of the footing have been found as indicated. The footing is to be founded on medium dense clayey sand. Using the given parameters, design this footing along the steps indicated below;



Grade of concrete (f_{cu})	- 30 MPa
Ch. strength of steel (f_y)	- 460 MPa
Design axial load on footing	- 100 kN
Design moment on footing	- 20 kNm
Unit weight of concrete	- 24 kN/m^3
Soil bearing capacity	- 150 kN/m^2
Nominal cover for reinforcement	- 40 mm

Service value = Design value / 1.5

Notes:
* Assume 10 mm dia. for main r/f
* Neglect the weight of soil above footing

All dimensions are in "mm"

i.) Check for soil bearing and possibility of lifting of the footing, under service loads and propose modifications if necessary,
(06 marks)

ii.) Design the flexural reinforcement for the critical section of the footing,
(05 marks)

iii.) Check for punching shear at the critical periphery and propose modifications if necessary,
(05 marks)

iv.) Produce a sketch of the reinforcement drawing, in the form of a plan and a cross section of the footing, using the standard method of detailing.
(04 marks)