The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	**:**	**MEX5232 Strength of Materials II**
Academic Year	:	2013/14
Date	:	04 – 08 - 2014
Time	:	9.30 a.m. – 12.30 p.m.
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **8** questions. All questions carry equal marks.
3. Answer any **5** questions only.
4. Formula sheet is provided at the end of the question paper.

Q1. A beam has a cross section as shown in Figure Q1. This beam is to be used as a cantilever over a length of 2m with AB on top. The Modulus of Elasticity of material of the beam is 200GPa.

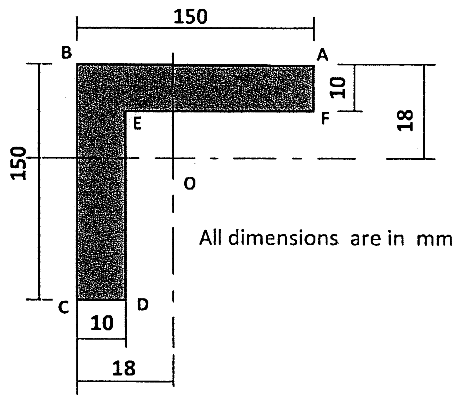

Figure Q1

(a) Find the second moment of area about the horizontal and vertical axes going through the centre of area **O**. *4 marks*

(b) If a point load of 4kN is applied at the free end of the cantilever vertically downward going through the centre of area **O**, determine the maximum compressive bending stress of the beam. *5 marks*

(c) Another point load of 2KN is applied at the free end horizontally on BC and going through the centre of area, in addition to the 4kN load. Determine the bending stress at point **C**. *5 marks*

(d) What would be the effect on the stresses on the beam section if the vertical 4kN load is shifted to point **A**? *6 marks*

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Q2. (a) State the first and the second Moment- Area theorems used to determine angular and vertical deflections of beams. **6 marks**

(b) A cantilever beam AC fixed at C carries a concentrated load and an external bending moment as shown in Figure Q2.

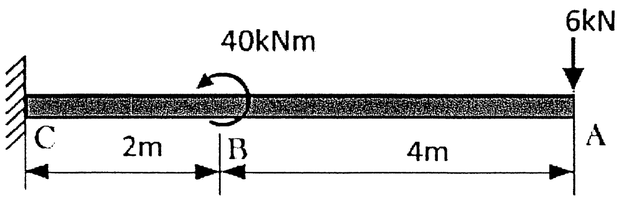

Figure Q2

(i) Sketch the bending moment diagrams due to the two loads. **4marks**

(ii) Use moment- area theorems to determine the slope and the vertical deflection at point A. Take EI as $3000kNm^2$. **10 marks**

Q3. A closed ended thick cylinder is to be designed to withstand an internal pressure of $20MN/m^2$ and an external pressure of $10MN/m^2$. The internal radius of the cylinder is 80mm. The hoop stress in the cylinder material should not exceed $30MN/m^2$.

(a) Sketch the radial and hoop stresses against $1/r^2$, taking external radius as r_2. Where r is the radius of the cylinder. **5 marks**

(b) Determine the external radius r_2 of the cylinder, with the aid of the sketch in (a). **10 marks**

(c) Find the hoop stress developed at the outer radius of the cylinder. **5 marks**

Q4. A compound cylinder, made out of same material having the modulus of elasticity $200GN/m^2$, has initial interface pressure of $5MN/m^2$, and has the following radii.

Internal: 100mm, Intermediate: 200mm, External: 300mm

(a) Sketch the radial and hoop stresses against $1/r^2$. **5 marks**

(b) Hence, determine,

(i) hoop stress values at the interface **5 marks**

(ii) shrinkage allowance **5 marks**

(c) An internal pressure of $5MN/m^2$ is applied to the cylinder. Sketch the variation of stresses against $1/r^2$ on the same axes drawn in (a) and find out the new interface pressure. **5 marks**

Q5 Following are the information for a compound cylinder made of two different materials named as material 1 and material 2.

Inner cylinder : Internal radius: 100mm, outer radius : 200mm
Outer cylinder: Outer radius: 300mm

Modulus of Elasticity (E), Poisson's ratio(ν), and coefficient of linear expansion(α) for the two materials are:

$E_1 = 100\ GN/m^2$, $\nu_1 = 0.33$, $\alpha_1 = 18 \times 10^{-6}\ ^oC^{-1}$
$E_2 = 200\ GN/m^2$, $\nu_2 = 0.30$, $\alpha_2 = 13 \times 10^{-6}\ ^oC^{-1}$

Suffixes 1 and 2 refer to material 1 and material 2 respectively.

(a) What material should be used for the inner cylinder if the compound cylinder is to be used at elevated temperatures? Explain the answer. *4 marks*

(b) If the temperature of the compound cylinder is raised by 20^oC, find the induced interface pressure considering that there is no shrinkage at the room temperature. *8 marks*

(b) If an initial interface pressure of $5MN/m^2$ is to be induced, what should be the total shrinkage at the room temperature? *8 marks*

Q6. (a) A solid shaft with a diameter 30mm is subjected to a torque T. What is the maximum value of T that can be transmitted by the shaft with a factor of safety of 3? *6 marks*
The modulus of rigidity and the yield shear stress of shaft material are 80GPa and 150MPa respectively.

(b) Determine the section area of a rectangular solid bar made of the same material that could transmit the same torque with the same factor of safety as given in (a). The ratio of longer side to the shorter side of the bar section is to be 1.5. *7 marks*

(c) Determine the mean radius of a thin walled tube of 3mm thick that can be used to transmit the same torque with the same factor of safety as in (b). *7 marks*

Q7 (a) What is meant by Shape Factor referred to in bending of beams beyond yield point? *4 marks*

(b) A simply supported beam of length 3m carries a uniformly distributed load of 4kN/m. The beam section is 30mm wide and 60mm deep.

(i) Determine the bending moment that sets in yielding at the top fibre of the beam. The yield stress of the material of the beam is $200MN/m^2$. *6 marks*

(ii) Is the beam under the given load is yielded beyond elastic limit? If so determine the depth to which plastic yielding has taken place. *6 marks*

(iii) Determine the position of the beam at which the yielding has just sets in at the top fibre. *4 marks*

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Q8 (a) State

(i) Maximum shear stress theory, and **4 marks**

(ii) Maximum principle stress theory, used in the prediction of failure of structural components.

(b) A shaft is used to transmit a torque of 10kNm. Yield stress of the shaft material is 250MN/m². **8 marks**

(i) Determine the diameter of the shaft according to **maximum shear stress theory.**

(ii) If the shaft diameter is 100mm and it is required to carry a tensile axial load in addition to the 10kNm torque, what would be the maximum allowable tensile load according to the maximum principle stress theory of failure? **8 marks**

Formula sheet

Thick cylinders

Lame equations

$$\sigma_r = A - \frac{B}{r^2}$$

$$\sigma_H = A + \frac{B}{r^2}$$

Compound cylinder with same material

$$\delta = \frac{r_2}{E}(\sigma_{Ho} - \sigma_{Hi})$$

Compound cylinder with different materials

$$\delta = \frac{r_2}{E_2}(\sigma_{H/2} + v_2 p) - \frac{r_2}{E_1}(\sigma_{H/1} + v_1 p)$$

$$\frac{1}{E_2}[\sigma_{H/2} + v_2 p] - \frac{1}{E_1}[\sigma_{H/1} + v_1 p] = \Delta T(\alpha_1 - \alpha_2)$$

$\sigma_r = radial\ stress$
$\sigma_H = Hoop\ stress$
$\delta = Total\ shrinkage$
$E = Modulus\ of\ Elasticity$
$p = Interface\ pressure$
$v = Poission's\ Ratio$
$\Delta T = Temperature\ change$
$\alpha = Coefficient\ of\ Linear\ Expansion$
Suffixes o and i refer to outer and inner cylinders
Suffixes 1 and 2 refer the two cylinders

Strain beyond elastic limit

The bending moment M_{pp} that gives yielding up to a point, at a distance $d/2$ from the Neutral Axis for rectangular section of width B and depth D is given by the following formula.

$$M_{PP} = \frac{B\sigma_y}{12}[3D^2 - d^2]$$

Torsion in rectangular sectioned solid shafts

The maximum shear stress for a rectangular solid shaft, with longer side **b** and shorter side **d** is given by the following formula.

$$\tau_{max} = \frac{T}{k_1 d b^2}$$

The angle of twist per unit length is given by

$$\frac{\theta}{L} = \frac{T}{k_2 d b^3 G}$$

k_1 and k_2 are constants depending on the ratio b/d

b/d	**1.0**	**1.5**	**1.75**	**2.0**	**2.5**	**3.0**	**4.0**	**6.0**	**8.0**	**10.0**	**∞**
k_1	0.208	0.231	0.239	0.246	0.258	0.267	0.282	0.299	0.307	0.313	0.333
k_2	0.141	0.196	0.214	0.229	0.249	0.263	0.281	0.299	0.307	0.313	0.333

Thin-walled closed tubes

Shear stress on a thin walled closed tube subjected to a torque is given by with usual notation,

$$\tau = \frac{T}{2At}$$