



SWANSEA METROPOLITAN UNIVERSITY

PRIFYSGOL FETROPOLITAN ABERTAWE

## EXAMINATION INTERNAL VERIFICATION FORM

|                                        |                                                                                    |                                     |         |
|----------------------------------------|------------------------------------------------------------------------------------|-------------------------------------|---------|
| MODULE :                               | Mechanical Principles                                                              | LEVEL:                              | 5       |
| PROGRAMME :                            | HND Motorsport / Automotive / Motorcycle Engineering                               | TERM OF EXAM:<br>(SPRING OR SUMMER) | PhT1    |
| LEARNING OUTCOME(S)<br>BEING ASSESSED: | 1. Analyse complex loading systems, loaded beams and thin walled pressure vessels. | EXAMINATION<br>AUTHOR :             | T.Tudor |

| VERSION: | DATE SUBMITTED<br>FOR VERIFICATION: | INTERNAL VERIFIER COMMENTS (Approval or detail of amendments required): | DATE:     |
|----------|-------------------------------------|-------------------------------------------------------------------------|-----------|
| 1.       | 27/09/13                            | Good as usual.                                                          | 27/09/13. |
| 2.       |                                     |                                                                         |           |

### INTERNAL VERIFIER PLEASE TICK TO INDICATE THAT THE EXAMINATION:

|                          |                                                                     |
|--------------------------|---------------------------------------------------------------------|
| <input type="checkbox"/> | Conforms to the assessment pattern described in the module syllabus |
| <input type="checkbox"/> | Tests the module learning outcome(s) appropriately                  |

### SIGNATURES OF FINAL APPROVAL:

| SIGNATURE                                                                                                                                                      | DATE     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                             | 27/09/13 |
| INTERNAL VERIFIER: I confirm that this version of the exam paper is ready to be sent to the external examiner                                                  |          |
| EXAM AUTHOR: I confirm that internal verifier and external examiner approval have been received and that this version of the exam paper is ready for printing. |          |



# EXAMINATIONS 2013 / 2014 AHOLIADAU 2013 / 2014

## Semester 1

**FACULTY OF:** Applied Design and Engineering

**NAME OF COURSE/PROGRAMME:** HND Motorsport/Automotive/Motorcycle Engineering

**COHORT ENTRY POINT (Autumn or Spring):** Autumn

**YEAR OR LEVEL:** Year 2

**NAME OF MODULE/EXAM PAPER:** Mechanical Principles : Phase Test 1

**MODULE NO:**

**DATE OF EXAMINATION:** January 2014

**EXAMINATION TIMES:**

**START TIME:** 9.00 AM

**FINISH TIME:** 11.00 AM

**TIME ALLOWED:** 2 hours

### INSTRUCTIONS TO CANDIDATES:

Answer **ALL** questions.

The mark allocation is as indicated – total **50 marks**.

A 'formula sheet' is provided for reference.

Assume 'g' =  $9.81 \text{ m/s}^2$ .

and  $1 \text{ bar} = 10^5 \text{ N/m}^2 (\text{Pa})$

### QUESTION ONE

At a certain point in a material there is a strain in the 'x' direction of  $-15 \times 10^{-6}$  and a strain in the 'y' direction of  $-22 \times 10^{-6}$ . The material has a Poisson's ratio of 0.26 and a Modulus of Elasticity of 180 GPa.

- i. Calculate the corresponding stresses in each direction at this point in the material and state whether they are compressive or tensile.
- ii. If at a second point in the material the stresses are found to be 64MPa (tensile) in the 'x' direction and -38 MPa (compressive) in the 'y' direction, calculate the corresponding strains.

(10 marks)

### QUESTION TWO

A cube, made from an Isotropic material, of side length 150mm is subjected to an external fluid pressure of 25 MPa.

- i. If the modulus of elasticity of the cube material is 180 GPa and the Poissons ratio is 0.24, calculate the bulk modulus and change in volume.
- ii. Explain what is meant by the term 'orthotropic' when discussing materials.

(10 marks)

### QUESTION THREE

A 1 m long cantilever beam carries a uniformly distributed load of 1000N/m along its entire length. A point load of 7 kN also acts at the free end of the beam. The beam has a flexural stiffness of 2 MPa.

Calculate

- i) The corresponding maximum deflection at the end of the beam
- ii) How much the point load may be increased before the deflection exceeds 1.5 mm

(10 marks)

### QUESTION FOUR

A thin walled cylinder is to act as an air receiver. It will have a diameter of 0.2m, and be 0.9m in length and is to be made from sheet steel. The longitudinal and circumferential joint efficiencies will be 62% and 70% respectively, and the maximum allowable stress in the material is 100 MPa. If the receiver is to hold a pressure of 20 Bar, calculate the minimum wall thickness required.

(10 marks)

### QUESTION FIVE

A hydraulic cylinder has an external diameter of 300 mm and an internal diameter of 260 mm. If it is pressurised internally to 150 Bar gauge, determine the radial and circumferential stresses at the inner and outer surfaces.

(10 marks)

# SOLUTIONS.

Q1 i)

$$\begin{aligned} \epsilon_x &= -15 \times 10^{-6} \\ \epsilon_y &= -22 \times 10^{-6} \\ \nu &= 0.26 \\ E &= 180 \times 10^9 \text{ N/m}^2 \end{aligned}$$

$$\sigma_x = \frac{E}{1-\nu^2} (\epsilon_x + \nu \epsilon_y) = \frac{180 \times 10^9}{1-(0.26)^2} (-15 \times 10^{-6} + (0.26 \times -22 \times 10^{-6}))$$

$$\sigma_x = -2.996 \text{ MPa} \quad \checkmark \text{ (compressive)}$$

~~$-4 \times 10^6$~~

$$\sigma_y = \frac{E}{1-\nu^2} (\epsilon_y + \nu \epsilon_x) = \frac{180 \times 10^9}{1-(0.26)^2} (-22 \times 10^{-6} + (0.26 \times -15 \times 10^{-6}))$$

$$\sigma_y = -5 \text{ MPa} \quad \checkmark \text{ (compressive)}$$

ii)

$$\begin{aligned} \sigma_x &= +64 \times 10^6 \text{ N/m}^2 \\ \sigma_y &= -38 \times 10^6 \text{ N/m}^2 \end{aligned}$$

$$\epsilon_x = \frac{1}{E} (\sigma_x - \nu \sigma_y) = \frac{1}{180 \times 10^9} (64 \times 10^6 - (0.26 \times -38 \times 10^6))$$

$$\epsilon_x = 300.7 \text{ } \mu\epsilon \quad \checkmark \quad 410.4 \times 10^{-6}$$

$$\epsilon_y = \frac{1}{E} (\sigma_y - \nu \sigma_x) = \frac{1}{180 \times 10^9} (-38 \times 10^6 - (0.26 \times 64 \times 10^6))$$

$$\epsilon_y = -303.6 \text{ } \mu\epsilon \quad \checkmark$$

Q2

$$\begin{aligned} L &= 0.15 \text{ m} \\ P &= 25 \times 10^6 \text{ N/m}^2 \\ E &= 180 \times 10^9 \text{ N/m}^2 \\ \nu &= 0.24 \end{aligned}$$

$$i) K = \frac{E}{3(1-2\nu)} = \frac{180 \times 10^9}{3(1-(2 \times 0.24))} = 115.38 \times 10^9 \text{ N/m}^2$$

$$K = \frac{\sigma}{\epsilon_v} = \frac{-P}{\epsilon_v}$$

$$\epsilon_v = \frac{-P}{K} = \frac{-25 \times 10^6}{115.38 \times 10^9} = -216.68 \times 10^{-6}$$

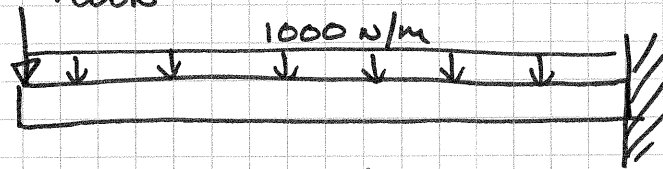
$$\epsilon_v = \frac{\Delta V}{V}$$

$$\Delta V = \epsilon_v V = -216.68 \times 10^{-6} \times (0.15)^3$$

$$\Delta V = -0.731 \times 10^{-6} \text{ m}^3$$

ii) Orthotropic materials have different elastic constants in different directions. This may be due to grain structure of tube directions in composites etc.

Q3  $L = 1\text{m}$   
 $EI = 2 \times 10^6 \text{ N/m}^2$   
 $7000\text{N}$



i) Deflection =  $\frac{F L^3}{3EI} + \frac{w L^4}{8EI}$

$$= \frac{-7000 \times 1^3}{3 \times 2 \times 10^6} + \frac{-1000 \times 1^4}{8 \times 2 \times 10^6}$$

$$= -1.1667 \times 10^{-3} - 0.0625 \times 10^{-3}$$

$$= -1.23 \times 10^{-3} \text{ m}$$

ii)  $y = y_{PL} + y_{udl}$

$$y_{PL} = y - y_{udl} = -1.5 \times 10^{-3} - (-0.0625 \times 10^{-3})$$

$$y_{PL} = ~~6 \times 10^{-3}~~ - 1.4375 \times 10^{-3}$$

$$y_{PL} = \frac{F L^3}{3EI}$$

$$\therefore F = \frac{y_{PL} \times 3EI}{L^3}$$

$$F = \frac{-1.4375 \times 10^{-3} \times 3 \times 2 \times 10^6}{1^3}$$

$$F = -8625 \text{ N}$$

$$\therefore DF = 1625 \text{ N}$$

Q4

$$d = 0.2 \text{ m}$$

$$L = 0.9 \text{ m}$$

$$\eta_L = 0.62 \checkmark$$

$$\eta_o = 0.7 \checkmark$$

$$\sigma_{\max} = 100 \times 10^6 \text{ N/m}^2$$

$$P = 20 \times 10^5 \text{ N/m}^2$$

$$\sigma_c = \frac{Pd}{2t\eta_L} \checkmark$$

$$\sigma_r = \frac{Pd}{4t\eta_c} \checkmark$$

$$t = \frac{Pd}{2\sigma_c\eta_L} \checkmark$$

$$t = \frac{Pd}{4\sigma_r\eta_c} \checkmark$$

$$t = \frac{20 \times 10^5 \times 0.2}{2 \times 100 \times 10^6 \times 0.62} \checkmark$$

$$t = \frac{20 \times 10^5 \times 0.2}{4 \times 100 \times 10^6 \times 0.7} \checkmark$$

$$t = 3.23 \text{ mm} \checkmark$$

$$t = 1.43 \text{ mm} \checkmark$$

$$\therefore t_{\min} = 3.23 \text{ mm} \checkmark$$

Q5  $d_o = 0.3\text{m}$   
 $d_i = 0.26\text{m}$   
 $P = 150 \times 10^5 \text{ N/m}^2$

$r_i = 0.13\text{m}$  ✓  
 $r_o = 0.15\text{m}$  ✓

@  $r_o = 0.15\text{m}$   $\sigma_r = 0$  ✓

$$\sigma_r = a - \frac{b}{r^2}$$

$$0 = a - \frac{b}{0.15^2}$$

$$0 = b - (0.15)^2 a \quad \textcircled{1} \checkmark$$

@  $r_i = 0.13$   $\sigma_r = -150 \times 10^5$  ✓

$$\sigma_r = a - \frac{b}{r^2}$$

$$-150 \times 10^5 = a - \frac{b}{0.13^2}$$

$$253500 = b - (0.13)^2 a \quad \textcircled{2} \checkmark$$

$\textcircled{2} - \textcircled{1}$   $253500 = -(0.13)^2 a + (0.15)^2 a$  ✓

$$a = \frac{253500}{0.15^2 - 0.13^2} = 45.27 \times 10^6 \text{ N/m}^2$$

$$b = 1.019 \times 10^6 \checkmark$$

@  $r_i$   $\sigma_c = a + \frac{b}{r^2} = 45.27 \times 10^6 + \frac{1.019 \times 10^6}{0.13^2} = 105.5 \text{ MPa}$

@  $r_o$   $\sigma_c = a + \frac{b}{r^2} = 45.27 \times 10^6 + \frac{1.019 \times 10^6}{0.15^2} = 90.56 \text{ MPa}$  ✓