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The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2021-2022

MECHANICS OF SOLIDS

Time allowed 40 minutes

Open-book take-home examination

Answer ALL questions

You must submit a single pdf document, produced in accordance with the guidelines provided on take-home examinations, that contains all of the work that you wish to have marked for this open-book examination. Your submission file should be named in the format '[Student ID]_MMME2053.pdf'.

Write your student ID number at the top of each page of your answers.

This work must be carried out and submitted as described on the Moodle page for this module. All work must be submitted via Moodle by the submission deadline. **Work submitted after the deadline will not be accepted without a valid EC.**

No academic enquiries will be answered by staff and no amendments to papers will be issued during the examination. If you believe there is a misprint, note it in your submission but answer the question as written.
Contact your Module Teams Channel or SS-AssessEng-UPE@exmail.nottingham.ac.uk for support as indicated in your training.

Plagiarism, false authorship and collusion are serious academic offences as defined in the University's Academic Misconduct Policy and will be dealt with in accordance with the University's Academic Misconduct Procedures. The work submitted by students must be their own and you must declare that you understand the meaning of academic misconduct and have not engaged in it during the production of your work.

ADDITIONAL MATERIAL: Formula sheet

SECTION A

1. Fig. Q1 shows a schematic of a waveform for stress-controlled fatigue testing, where:

   i. S_{min} = Minimum Stress
   ii. S_{max} = Maximum Stress
   iii. S_{mean} = Mean Stress
   iv. S_{range} = Stress Range
   v. S_{amp} = Stress Amplitude

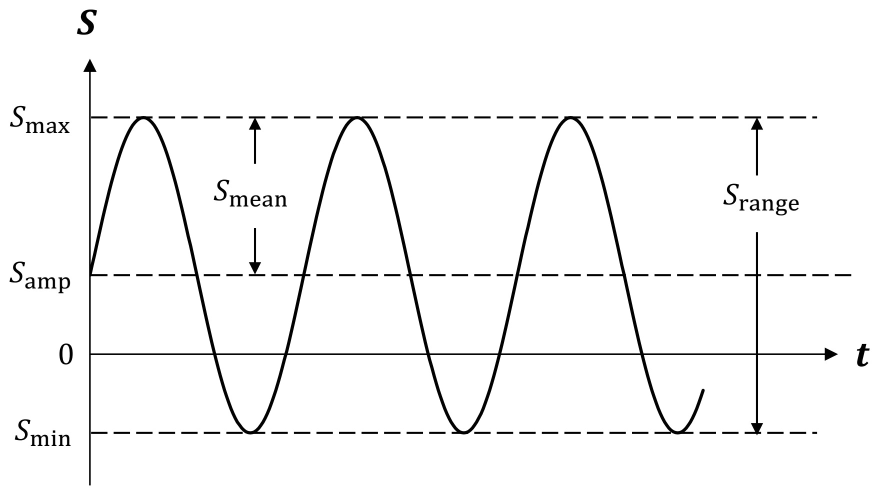

Fig. Q1

i to v are labelled correctly in Fig Q1.

A. True
B. -
C. -
D. -
E. False

[2]

2. Under fatigue, materials usually fail in three stages, the second being crack propagation and the final being final fracture. What is the first stage?

A. Crack initiation
B. Brittle failure
C. Ductile tearing
D. No change
E. Crack closure

[2]

3. For the same loading case, would a drive shaft designed using the Tresca yield criterion be (the same or) bigger or smaller in diameter than the equivalent using the von Mises yield criterion?

A. Bigger
B. -
C. -
D. -
E. Smaller

[2]

4. The feature labelled A in Fig. Q4 is the:

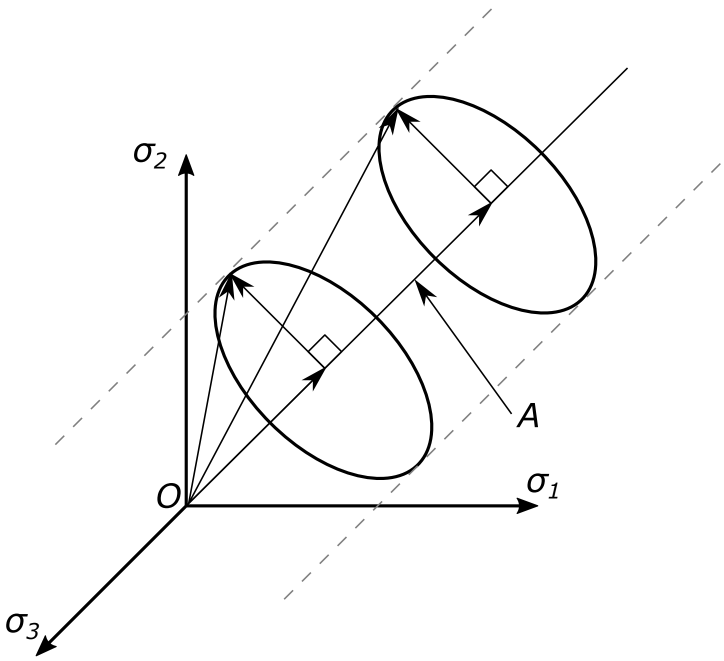

Fig. Q4

A. Hydrostatic Stress
B. Deviatoric Stress
C. π-plane
D. Deviatoric Plane
E. Principal Stress

[2]

5. Fig. Q5 shows a beam which is simply supported at positions A and D and has an applied point moment, M_B, at position B, and an applied point load, P_C, at position C. Taking the origin as the left-hand side of the beam, which of the following expresses the 2nd order differential equation for this beam?

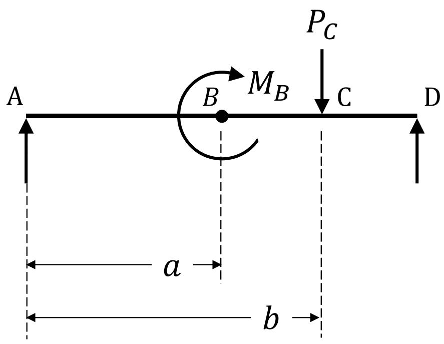

Fig. Q5

A. $\frac{d^2y}{dx^2} = R_A x + M_B\langle x-a\rangle^0 - P_C\langle x-b\rangle$

B. $EI\frac{d^2y}{dx^2} = R_A + M_B\langle x-a\rangle^0 - P_C\langle x-b\rangle + A$

C. $\frac{d^2y}{dx^2} = R_A x + M_B\langle x-a\rangle + P_C\langle x-b\rangle$

D. $EI\frac{d^2y}{dx^2} = R_A x - M_B\langle x-a\rangle^0 - P_C\langle x-b\rangle$

E. $EI\frac{d^2y}{dx^2} = R_A x + M_B\langle x-a\rangle^0 - P_C\langle x-b\rangle$

[2]

6. What is the corresponding expression for slope in the beam shown in Fig. Q5?

A. $\frac{dy}{dx} = \frac{R_A x^2}{2} + M_B\langle x-a\rangle - \frac{P_C\langle x-b\rangle^2}{2} + A$

B. $\frac{dy}{dx} = \frac{1}{EI}\left(\frac{R_A x^2}{2} + M_B\langle x-a\rangle - \frac{P_C\langle x-b\rangle^2}{2} + A\right)$

C. $EI\frac{dy}{dx} = R_A x + M_B\langle x-a\rangle - \frac{P_C\langle x-b\rangle^2}{2} + Ax + B$

D. $EI\frac{dy}{dx} = \frac{R_A x^2}{2} + M_B\langle x-a\rangle - \frac{P_C\langle x-b\rangle^2}{2} + A$

E. $\frac{dy}{dx} = \frac{1}{EI}\left(\frac{R_A x^2}{2} - M_B\langle x-a\rangle - \frac{P_C\langle x-b\rangle^2}{2} + A\right)$

[2]

7. If $P_C = 2000\text{ N}$, $M_B = 750\text{ Nm}$, $a = 0.5\text{ m}$, $b = 0.75\text{ m}$, and the length of the beam $L = 1\text{ m}$, what is the reaction force at position A in the beam in Fig. Q5?

A. 2187.5 N
B. 1750 N
C. −250 N
D. 1666.7 N
E. 2916.7 N

[2]

8. A hollow shaft with an outer diameter of 43 mm, and a wall thickness of 3.75 mm, will carry a torque of 425 Nm and an axial load of 23.75 kN. What is the maximum principal stress on a 2D plane stress element on the surface of the shaft?

A. $-104.8\ \text{MPa}$
B. $82.6\ \text{MPa}$
C. $72.3\ \text{MPa}$
D. $-31.2\ \text{MPa}$
E. $113.9\ \text{MPa}$

[2]

9. An unconstrained, $2.1\ \text{m}$ long steel bar is subjected to a temperature change of $19\ °\text{C}$. What is the change in length of the bar? ($\alpha = 12.5 \times 10^{-6}\ °C^{-1}$, $E = 207\ \text{GPa}$)

A. $8.26 \times 10^{-4}\ \text{m}$
B. $4.99 \times 10^{-4}\ \text{m}$
C. $3.93 \times 10^{-4}\ \text{m}$
D. $2.495 \times 10^{-4}\ \text{m}$
E. $1.87 \times 10^{-4}\ \text{m}$

[2]

10. Which of the cross-sections shown in Fig. Q10 has the largest 2nd moment of area about the Y-Y axis (which passes through the centroids of each cross-section)?

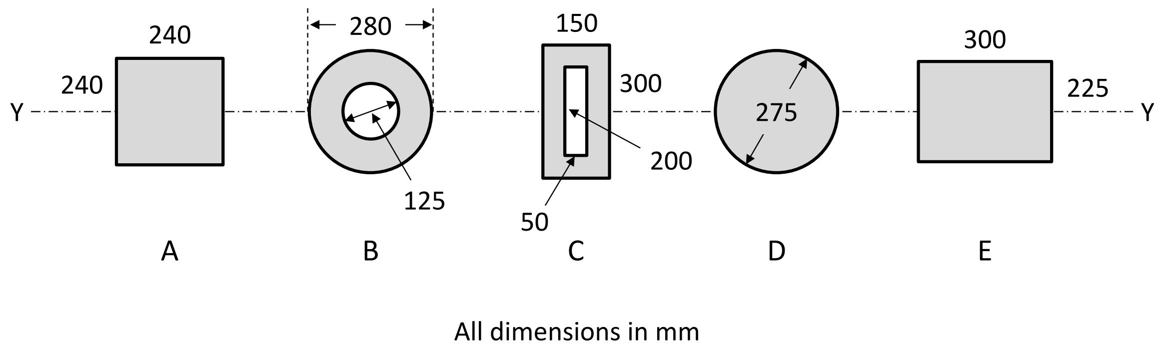

Fig. Q10

A. A
B. B
C. C
D. D
E. E

[2]

11. What would the edge length of a solid square cross-section need to be to match the largest 2nd moment of area from Q10?

A. $280.6\ \mathrm{mm}$
B. $240.9\ \mathrm{mm}$
C. $132.1\ \mathrm{mm}$
D. $164.2\ \mathrm{mm}$
E. $245.8\ \mathrm{mm}$

[2]

12. If the square cross-sectional beam from Q11 has a yield stress, $\sigma_y = 213\ \mathrm{MPa}$, and is subjected to a pure bending moment of $315\ \mathrm{kNm}$, does yielding occur?

Assume elastic-perfectly-plastic material behaviour.

A. Yes
B. -
C. -
D. -
E. No

[2]

13. Which of the shaft loading cases below results in the largest value of maximum in-plane principal stress acting on a 2D plane-stress element on the surface of a $27\ \mathrm{mm}$ radius, solid shaft? T = Torque, P = Axial Force, M = Pure Bending Moment.

A. $T = 175\ \mathrm{Nm}$, $P = 175\ \mathrm{N}$, $M = 185\ \mathrm{Nm}$
B. $T = 175\ \mathrm{Nm}$, $P = 185\ \mathrm{N}$, $M = 195\ \mathrm{Nm}$
C. $T = 195\ \mathrm{Nm}$, $P = 160\ \mathrm{N}$, $M = 175\ \mathrm{Nm}$
D. $T = 185\ \mathrm{Nm}$, $P = 180\ \mathrm{N}$, $M = 210\ \mathrm{Nm}$
E. $T = 285\ \mathrm{Nm}$, $P = 170\ \mathrm{N}$, $M = 125\ \mathrm{Nm}$

[2]

14. What is the value of the maximum in-plane principal stress for the 2D plane-stress element shown in Fig. Q14?

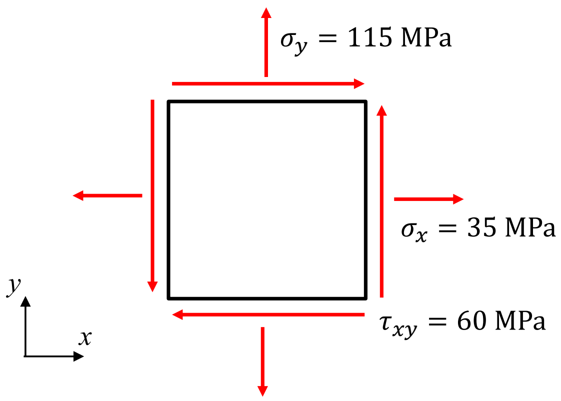

Fig. Q14

A. 147.1 MPa
B. 40 MPa
C. 91.8 MPa
D. 14.8 MPa
E. 210.2 MPa

[2]

15. For a cracked component, for which $K_I = 2.47\sigma\sqrt{\pi a}$, $K_{Ic} = 106\ \text{MPa}\sqrt{\text{m}}$ and $\sigma_y = 213\ \text{MPa}$, calculate the critical crack length, a_c, if the material behaves in a linear elastic manner and $\sigma = \frac{3}{5}\sigma_y$.

A. 35.9 mm
B. 12.9 mm
C. 11.4 mm
D. 112.7 mm
E. 106.9 mm

[2]

16. An aluminium rod with a cross-sectional area of $100\ \text{mm}^2$ is stretched between two fixed points. The tensile load at 21 °C is 2570 N. What will be the stress at 85 °C?
Assume $\alpha = 20 \times 10^{-6}\ °\text{C}^{-1}$, $E = 72\ \text{GPa}$.

A. 25.3 MPa
B. – 96.7 MPa
C. −4.5 MPa
D. −66.5 MPa
E. 21.1 MPa

[2]

17. A solid circular shaft, made of a material with $\sigma_y = 283\ \text{MPa}$, will carry a torque of 20.5 kNm. According to the Tresca yield criterion, what is the minimum radius required to avoid yielding?

A. 35.9 mm
B. 9.6 mm
C. 45.1 mm
D. 28.5 mm
E. 66.2 mm

[2]

18. In the design of a new service component, once yielding has occurred within the material, elastic-linear hardening material behaviour is:

A. Always more conservative than elastic-perfectly-plastic material behaviour
B. Always less conservative than elastic-perfectly-plastic material behaviour
C. The only option
D. Always less conservative than elastic non-linear hardening material behaviour
E. Always more conservative than elastic non-linear hardening material behaviour

[2]

19. Figure Q3 illustrates which type of material behaviour?

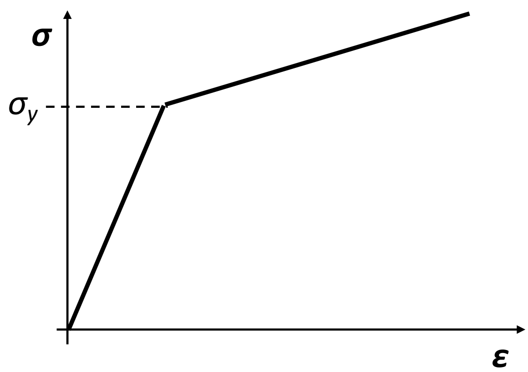

Figure Q3

A. elastic-perfectly-plastic
B. linear softening
C. non-linear elasticity
D. non-linear hardening
E. linear hardening

[2]

20. Which stress component is important in determining yield according to the von Mises and Tresca yield criteria?

A. Hydrostatic stress
B. Direct stress
C. Deviatoric stress

D. Principal stress
E. Shear stress

[2]